Chapter 20: Baseline Conditions in Ohio

INTRODUCTION

Section IV of this EEBA focuses on the state of Ohio as a case study of the MP&M regulation's expected benefits and costs. Ohio has a diverse water resource base, a relatively large number of MP&M industry facilities, and a more extensive water quality ecological database than many other states. EPA gathered extensive data on MP&M facilities and on Ohio's baseline water quality conditions and water-based recreation activities to support the case study analysis. These data characterize current water quality conditions, water quality changes expected from the regulation, and the expected welfare changes from water quality improvements at water bodies affected by MP&M discharges.

The case study analysis supplements the national-level analysis performed for the MP&M regulation in two important ways. First, the case study used improved data and methods to determine MP&M pollutant discharges from both MP&M facilities and other sources. In particular, EPA administered 1,600 screener questionnaires in the state of Ohio to augment information on Ohio MP&M facilities. The Agency also used information from the sampled MP&M facilities to assign discharge characteristics to non-sampled MP&M facilities[1]. Second, the analysis used an original travel cost study to value four recreational uses of water resources affected by the regulation: swimming, fishing, boating, and near-water activities. The added detail provides a more complete and reliable analysis of water quality changes from reduced MP&M discharges. The case study analysis therefore provides more complete estimates of changes in human welfare resulting from reduced health risk, enhanced recreational opportunities, and improved economic productivity.

CHAPTER CONTENTS

The statewide case study of recreational benefits from the MP&M regulation combines water quality modeling with a ***random utility model (RUM)*** to assess how changes in water quality from the regulation will affect consumer valuation of water resources. The study addresses a wide range of pollutant types and effects, including water quality measures not often addressed in past recreational benefits studies. The estimated model supports a more complete analysis of recreational benefits from reductions in ***nutrients*** and "toxic" pollutants.[2]

[1] Appendix H provides a detailed discussion on the approach used to estimate discharge characteristics for non-sampled MP&M facilities.

[2] The term "toxic" used here refers to the 126 ***priority or toxic pollutants*** specifically defined as such by EPA, as well as ***nonconventional pollutants*** that have a toxic effect on human health or aquatic organisms.

This and the next two chapters present the Ohio case study. This chapter provides background information on the state of Ohio, the following chapter presents the results from the recreational benefits analysis, and the last chapter summarizes social costs and benefits of the final regulation for the state of Ohio.

20.1 Overview of Ohio's Geography, Population, and Economy

Table 20.1 summarizes general information on Ohio. Ohio is large, heavily-industrialized, and densely-populated. The state covers a total surface area of 44,828 sq. mi. (106,607 sq. km.), of which water represents 3,875 sq. mi. (10,036 sq. km.). About 90 percent of the water surface area consists of Lake Erie; the remainder includes inland waters, such as lakes, reservoirs, and rivers (including the Ohio River). The state housed 11,353,140 people in 2000. The three largest metropolitan areas are located on Lake Erie (Toledo and Cleveland) and the Ohio River (Cincinnati).

Table 20.1: Facts about the State of Ohio

Geography			
Location	Midwest United States, northeast part: south of Lake Erie east of Indiana north of the Ohio River		
Total land area	40,953 sq. mi. (106,607 sq. km.) Of the 26,451,000 acres of terrestrial surface area in Ohio: 97 percent is non-federal land (National Resources Inventory (NRI)) 3,558,000 acres, representing 13.5 percent of the total area of Ohio, are developed The remaining non-federal lands are rural land, classified mostly as crop land, forest, and pasture lands. (USDA, 1992a)		
Total water surface area	3,875 sq. mi. (10,036 sq. km.) Approximately 90 percent is represented by Lake Erie, and 10 percent are inland waters including rivers, lakes, and reservoirs.[a]		
Total area	44,828 sq. mi. (116,104 sq. km.)		
Demographics			
Population	11,353,140 in 2000, approximately 4 percent of total U.S. population (U.S. Census Bureau) Population increase: 4.7 percent from 1990 to 2000, compared to a 13.1 percent increase in the U.S. population overall. Most densely populated part of the state: northeastern Ohio, both urban and rural areas. Largest cities: Cleveland, Cincinnati, and Toledo.		
Economics			
	Ohio	**Midwest**	**U.S.**
Per capita income (1996$)	$23,537 Rank in per capital income in the U.S.: 21	$24,166	$24,231
Percent of population below the poverty level (1995 Current Population Survey data, DOC 1996)	11.5%	N/A	13.8%
	Ohio per capita income increased by 16 percent from 1986 to 1996. Income growth is consistent with other midwestern states and is 2 percent greater than overall U.S. per capita income growth.		
Gross State Product (GSP)	$303,569,000,000 (1996$), representing 4 percent of Gross Domestic Product (GDP) for the U.S. in 1996.		
Percent increase in GSP/GDP from 1986 to 1996 (in adjusted 1996$)	Ohio GSP: 25%	U.S. GDP: 29%	

[a] Total water surface areas are estimated by the USDA's National Resources Inventory (NRI) (USDA 1992b). (http://www.ftw.nrcs.usda.gov/nri_data.html)

Source: U.S. EPA analysis.

20.2 PROFILE OF MP&M FACILITIES IN OHIO

EPA selected Ohio as the case study state because MP&M industries account for a large share of the state's economy (see Table 20.2). Data from the 1997 Economic Censuses show that industries containing MP&M facilities employ 19.8 percent of Ohio's total industrial workers and produce 21.2 percent of industrial worker output by value. MP&M industries also account for 22.1 percent of payroll payments, indicating that jobs in MP&M industries are more highly paid than industrial jobs on average in Ohio. The discussion below explains the sources and methodology EPA used, and then presents detailed results and caveats.

Table 20.2: MP&M Share of Industrial Output and Employment in Ohio, 1997

	Total Employment	Payroll	Value of Output
MP&M	827,507	$23,233,857,000	$132,117,226,000
Total	4,087,393	$112,777,104,000	$677,978,137,000
MP&M Share	**19.8%**	**22.1%**	**21.2%**

Source: Department of Commerce 1992 Economic Censuses.

EPA obtained employment, payroll, and output data from the 1997 Economic Census CD-ROM, drawing from the eight economic censuses in Table 20.3. Employment and payroll numbers include all employees (i.e., production plus non-production workers). The measure of output differs according to the source, but in each case the output measures shown in Table 20.2 correspond conceptually to total revenue. EPA extracted the EMPLOYEE, PAYROLL, and VALUE fields for each 4-digit SIC industry in the MP&M category and for the entire state of Ohio. Industries include both in-scope and out-of-scope facilities.

Table 20.3: The Economic Censuses

Source	Measure of Output
Census of Retail Trade	Value of sales
Census of Wholesale Trade	Value of sales
Census of Service Industries[a]	Value of receipts
Census of Transportation, Communications, and Utilities	Value of revenue
Financial, Insurance, and Real Estate Industries	Value of receipts
Census of Manufacturers	Value of shipments
Census of Mineral Industries	Value of shipments
Census of Construction Industries	Value of construction work

[a] Includes both taxable and non-taxable establishments.

Source: Department of Commerce 1997 Economic Censuses.

The MP&M industries include facilities to which the MP&M rule may not apply. For example, MP&M industries include non-dischargers, but census data do not distinguish between in-scope and out-of-scope facilities. In addition, EPA substantially revised the scope of the final regulation by excluding from the final regulation all indirect dischargers and direct dischargers in all subcategories except for Oily Wastes. Definition of MP&M subcategories is provided in Section 4.1 of this report. The final rule applies to an estimated 172 direct discharging facilities in Ohio.

Also, the analysis examines only the industrial sectors for which the Department of Commerce compiles statistics in the Economic Censuses. Published industrial employment and output measures often exclude military and other government personnel and farm output and employment, whether those exclusions are noted or not. The analysis excludes $4.7 billion in value of agricultural products sold in 1997 by farms in Ohio, according to the U.S. Department of Agriculture's 1997 Census of Agriculture. The Ohio analysis also excludes the government sector, which employed approximately 760,000 people in

Ohio in 1997, according to the U.S. Bureau of Labor Statistics.[3] These exclusions are normal when economists compare the size of industrial groups.

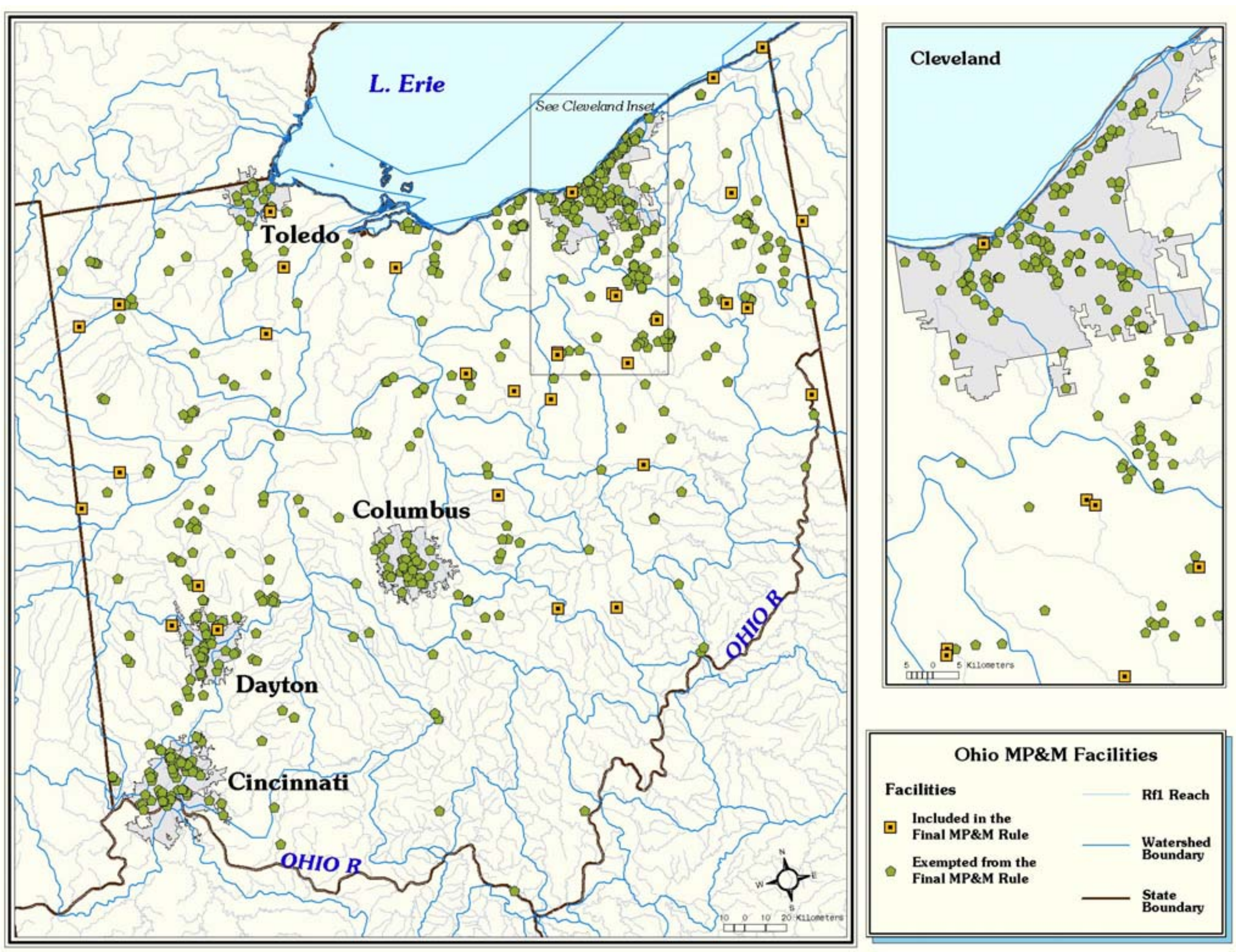
If total employment in Ohio includes the government sector, then MP&M industries account for only 16.7 percent, rather than 19.8, percent of employment. If total industrial manufacturing and non-manufacturing output in Ohio includes the agricultural sector, then MP&M industries account for only 21.0, rather than 21.1, percent of output. This said, data from the Bureau of Labor Statistics and USDA are not completely consistent with the Economic Census data.

EPA augmented information on MP&M facilities available from published data sources and the Section 308 survey by oversampling the state of Ohio with 1,600 screeners. The Agency used information from the Section 308 survey and the 1,600 screeners to characterize discharges from MP&M facilities in Ohio and to assess the economic impact of the final regulation at the state level. Figure 20.1 depicts locations of the Ohio facilities included in the case study analysis.

The map of facility locations shows that the additional information from 1,600 screeners enabled EPA to perform the benefits assessment with a greater level of detail than is possible at the national level. The added detail results in a more complete and reliable analysis of changes in human welfare resulting from reduced health risk and improved recreational opportunities.

[3] U.S. Bureau of the Census, *Statistical Abstract of the United States, 1993*, Washington, D.C., 1993.

Figure 20.1: Location of Sample MP&M Facilities in Ohio



Source: U.S. EPA analysis.

20.3 OHIO'S WATER RESOURCES

The benefits of enhanced water quality stem directly from enhancing water quality and/or quantity of services provided by water resources. To aid in understanding the analysis of benefits from the final rule in Ohio, this section summarizes environmental services provided by Ohio's water resources.

Ohio is a water-rich state:

- 24,000+ miles of named and designated rivers and streams;
- 451-mile border on the Ohio River;
- 200,000 acres among 450 lakes, ponds, rivers, and reservoirs; and
- 230+ miles of Lake Erie shoreline.

These water resources provide three broad categories of services: ***in-stream***, ***withdrawal***, and ***existence services***. Water resources provide in-stream services prior to the withdrawal of water from the water body. Major in-stream services include life support for animals and plants, water-based recreation, commercial fishing and navigation, water storage, and aesthetics. Withdrawal services include uses of water resources after the water is withdrawn from the water body. These uses include drinking water supply, irrigation, production and processing services, and sanitary services. Existence services are not linked to current uses of water bodies, and arise from knowing that species diversity or the natural beauty of a given water body is preserved.

The Ohio Environmental Protection Agency (Ohio EPA) assesses surface waters in their ***Ohio Water Resource Inventory (OWRI)*** report based on water resource services provided by the assessed water body. The main focus of this assessment is on beneficial uses associated with Ohio's water resources, including aquatic life use, recreation, and public water supply. Table 20.4 shows how Ohio surface waters fall into these use designations.

Table 20.4: Summary of Designated Life Uses for Ohio Surface Waters (1996)

Use Designation	Stream/River (Miles)[a]	Lakes / Reservoir (Acres)[a]	Lake Erie (Shore Miles)[a]
Total	43,917	200,000	236
Aquatic Life Use[a]	24,067	193,903	236
Exceptional Warmwater Habitat (EWH)	3,217	193,903	236
Warmwater Habitat (WWH)	18,318		
Other	2,532		
Recreation			
Primary Contact (PCR)[b]	224,96	200,000	236
Secondary Contact (SCR)	1,188		
Public Water Supply		118,801	

[a] Total river/stream miles are based on Ohio EPA estimates. U.S. EPA estimates 61,532 total river miles and 29,113 total perennial miles based on RF3, which includes many smaller undesignated streams.
[b] Note that some water bodies have more than one designated use (e.g., aquatic life and primary recreation).

Source: Ohio EPA, OWRI, 1996.

The aquatic life use category is further subdivided into seven categories. The most widely-applied aquatic use designation in Ohio is ***Warmwater Habitat (WWH)***, accounting for 18,318 (76 percent) stream and river miles (Ohio EPA, OWRI, 1996). The second most widely applied designation is ***Exceptional Warmwater Habitat (EWH)***, accounting for 3, 217 stream and river miles (13 percent), 236 Lake Erie shore miles (100 percent), and 193,903 acres of inland lakes (100 percent). Other aquatic life categories include:

- ***Modified Warmwater Habitat (MWH)***,
- ***Limited Resource Waters (LRW)***,
- ***Limited Warmwater Habitat (LWH)***,
- Seasonal Salmonid Habitat ***(SSH)***, and
- ***Coldwater Habitat (CWH)***.

Recreational uses are subdivided into ***Primary Contact Recreation (PCR)*** and ***Secondary Contact Recreation (SCR)***:

- Primary Contact Recreation (PCR) rivers and streams deep enough for full human body immersion activities, such as swimming.
- Secondary Contact Recreation (SCR) only deep enough to permit wading and incidental contact, such as boating.

Approximately half of the designated stream miles, all inland lakes, and all of the Lake Erie shore miles are designated for PCR (see Table 20.4). In addition, three percent of the designated stream miles (1,188 miles) are suitable for SCR.

The following sections detail each category of water resource use.

20.3.1 Aquatic Life Use

The Ohio water resources support hundreds of aquatic species and plants. Ohio water resources are also home to a number of endangered and threatened species. Suitable stream and lake habitat are essential for both resident and transient animal populations, including imperiled aquatic species. Habitats include specific ***biotic*** components (e.g., assemblages of plant and animal species) and physical (e.g., ***dissolved oxygen (DO)*** content and temperature range) components. Water quality impairments associated with siltation, excess nutrients, or low DO can adversely affect habitats that support important activities, such as reproduction, foraging, migration, and overwintering.

The following sections briefly introduce water-dependent biological resources in Ohio. Water quality effects on life support for animals and plants are discussed in Section 20.5

a. Ohio fish species

Fish are found throughout Ohio in almost every inland surface water body and Lake Erie. Many fish species serve important recreational or commercial functions, while others are important forage for birds, other fish, and land-based species. Ecosystem well-being therefore depends on the health of fish and other aquatic species populations. The Ohio EPA monitors biological data, especially those on sensitive aquatic species, to determine the aquatic life use attainment of surface waters. The state gives high priority to healthy aquatic ecosystem maintenance.

Ohio's rivers and lakes offer a variety of man-made and natural habitats that offer excellent fishing opportunities for numerous gamefish species. The state of Ohio spends significant resources on fishery management, trout stocking, and recreational area maintenance to enhance these fish populations. Table 20.5 below provides brief summaries of the habitat and diet of major recreational and commercial fish species in Ohio (Ohio DNR, 1999).

Table 20.5: Recreationally or Commercially Valuable Fish Species in Ohio

Fish	Native or introduced?	Habitat	Spawning season	Diet
Bass	Most native bass (e.g., largemouth, smallmouth, spotted, and sock)	Ponds, lakes, rivers, and streams in every county; Lake Erie	Mid-April to mid-June	Frogs, crayfish, insects, and other fish
Bullhead	Native	Throughout Ohio; concentrations in northern and west central Ohio	Mid-May to June	Insect larvae, crayfish, snails, dead animals
Burbot	Native	Lakes and rivers; prefer deep waters, but move inshore to spawn	Winter	Minnows and the young of other fish species
Carp	Introduced	Warm lakes, streams, and ponds with abundant organic matter, in every county	Late April to June	Insect larvae, mollusks, fish, crustaceans
Catfish (channel, flathead)	Native	Throughout Ohio's rivers and lakes; tolerate a wide range of conditions	When waters reach 70° F in temperature	Bottom feeders with a diet of insect larvae, mollusks, and fish both dead and alive

Table 20.5: Recreationally or Commercially Valuable Fish Species in Ohio

Fish	Native or introduced?	Habitat	Spawning season	Diet
Crappie, white		Larger ponds, reservoirs, and rivers, including near-shore habitats of Lake Erie, in most areas of Ohio	May and June	Insects and small fish
Crappie, black		Same general habitat as white crappie, slightly less widely distributed	May and June	Insects and small fish
Drum	Native	Lake Erie; drums support a commercial fishery	Spring into late summer	Mollusks, crayfish, fish, insects
Lamprey		Lake Erie and tributaries; Ohio River and larger tributaries		Some species parasitize other fish by attaching themselves to a larger host's flank and feeding on its flesh
Muskellunge (Muskie)	Native	Historically found in Lake Erie bays and tributaries and streams of Ohio River drainage; now also found in several impoundments	April and early May, when temperatures reach low- to mid-50s	Suckers, gizzard shard, and other soft-rayed fish
Perch, white	Introduced	Lake Erie and tributaries	April and May	Insects, crustaceans, other fish
Perch, yellow	Native	Lakes, impoundments, ponds, slow-moving rivers	April and May	
Pike	Native	Historically abundant in Lake Erie and tributaries; today distributed in a small portion of Lake Erie, Sandusky Bay, Maumee Bay, and their tributary streams in marshes, bays, and pools with abundant vegetation	As ice breaks in late February and early March Pike is a popular ice-fishing species	Mostly fish, but are opportunistic feeders; will occasionally eat frogs, muskrats, small ducks
Salmon (chinook and coho)	Introduced	Stocked in Lake Erie for both recreational and commercial fishing purposes		
Sauger	Native	Lake Erie and its tributaries; Ohio River	Spring, when water temperatures reach high 40s	Insects, crayfish, other small fish during low light (dawn and dusk)
Saugeye (cross between sauger and walleye)	Introduced	Stocked into many Ohio impoundments		
Sucker, white	Native	Every county; Lake Erie	April to May	Bottom feeders, consuming various plant and animal species
Sunfish	Bluegill, pumpkinseed, green, warmouth, and longear sunfish are native; redear sunfish are introduced	Rivers, streams, and lakes throughout Ohio, and Lake Erie	Between May and August	Adults feed mostly on smaller fish, insects, crustaceans

Table 20.5: Recreationally or Commercially Valuable Fish Species in Ohio

Fish	Native or introduced?	Habitat	Spawning season	Diet
Trout	Lake and brook trout are native; rainbow and brown trout are introduced and maintained by stocking	Lake trout populations are stocked in Pennsylvania and New York and are not highly prevalent in Ohio and Lake Erie waters; Brook trout are stocked in several locations throughout Ohio		
Walleye	Native	Historically found in Lake Erie, but has been stocked in the Ohio River and reservoirs throughout the state	April	Shiners, gizzard shad, alewives, rainbow smelt
Whitefish	Native	Shallow bays of Lake Erie's western basin		Bottom feeders with a diet of mollusks and insect larvae

Source: U.S. EPA analysis.

b. Other species dependent on aquatic resources

Resident and migratory bird species make extensive use of Ohio waters. Areas along the banks or shorelines of rivers, streams, lakes, ponds, and reservoirs provide high quality nesting areas; the waters themselves are an abundant source of food. Ohio waters also serve as important staging areas for birds migrating to or from points north or south. Wading or aquatic birds are generally unaffected by water quality impairments directly. They are affected indirectly, however, through feeding on fish or invertebrates whose populations may be affected by point and non-point pollution sources. The regulations aimed at protecting aquatic species will therefore benefit wading and aquatic bird species indirectly. More than 130 aquatic bird species rely on Lake Erie and its tributaries. Many species are also found near inland surface waters. Major classifications of birds in Ohio include (Ohio DNR, 1999):

- Waterfowl, residing year-round in Ohio waters, especially Lake Erie. Large groups of migrating and breeding birds are also found elsewhere in the state. More than 30 species are associated with the Great Lakes area alone. All species depend on fish and crustaceans or aquatic plants for feeding. Waterfowl include loons, grebes, swans, ducks and geese. The trumpeter swan is of particular interest to Ohio, which became one of several states involved in efforts to restore these birds to the Midwest beginning in 1996 (Ohio DNR, 1999).

- Wading birds, including bitterns, herons, and egrets. These species both reside in Ohio waters and use them as breeding grounds. They use “stand-and-wait” methods to catch fish or other aquatic organisms in shallow waters. Many wading birds, such as the great egret, black-crowned night heron, and American bittern, frequent Lake Erie and surrounding areas.

- Marsh birds, including rails, moorhens, coots, and gallinules. They may feed on insects, crustaceans, mollusks, frogs, invertebrates, and small fish. These bird populations suffer from excessive development and habitat destruction. Ohio surface waters, especially those around Lake Erie, can serve as important breeding grounds for these and other bird species.

- Shore birds, including 42 species of plovers, sandpipers, gulls, and terns, in the Lake Erie and other Ohio areas. Many of them feed on aquatic organisms from Lake Erie.

- Raptors, including the bald eagle and osprey. These birds of prey rely on fishing for a large part of their diet. Bald eagles are also a nationally-listed threatened species.

- The belted kingfisher, which relies on fish in Ohio waters as a main source of food.

Ohio’s biological resources also includes reptiles. Several species of lizards, snakes, and turtles depend on aquatic habitats for food and breeding. These reptiles include:

- Lizards - The five-fined skink, reported in areas along Lake Erie, can be found throughout Ohio.

- Snakes - The eastern fox snake, Eastern massasasuga, eastern ribbon snake, copperbelly water snake, Lake Erie water snake, and northern water snake feed within aquatic habitats.

- Turtles - The midland smooth softshell turtle and eastern spiny softshell turtle, found in the Ohio River and tributaries, are among Ohio turtles requiring aquatic habitats.

20.3.2 Water Recreation in Ohio

EPA used the 1994 ***Survey of National Demand for Water-based Recreation (NDS)*** (U.S. EPA, 1994) to characterize recreational uses of Ohio's water resources. The 1994 survey collected data on demographic characteristics and water-based recreation behavior using a nationwide stratified random sample of 13,059 individuals aged 16 and over. Respondents reported on water-based recreation trips taken within the previous 12 months, including the primary purpose of their trips (e.g., fishing, boating, swimming, and viewing), total number of trips, trip length, distance to the recreation site(s), and number of participants. EPA estimated recreational water use in Ohio by taking the following steps:

- estimate the percentage of survey respondents that visited Ohio, by state;

- apply this percentage to the total number of state residents aged 16 and over, to yield the total number of participants from each state;

- estimate the total number of recreation trips during the 12-month period for in-state and out-of-state participants;

- estimate the total number of recreation trips for out-of-state participants by multiplying an average number of trips per Ohio water body visitor by the total number of participants from each state;

- estimate the average number of annual trips per out-of-state visitor based on the number of times the respondents visited the site of their last recreational trip (i.e., Ohio water body).[4] EPA assumed that Ohio residents whose last recreation trip was in-state used Ohio water bodies for all of their recreation trips during the 12-month period; and

- estimate the total number of in-state trips, summing the weighted number of recreation trips over all Ohio respondents.

EPA found that:

- An estimated one million individuals made about 6.3 million boating trips to Ohio waters in 1993. In-state residents made 90 percent of the boating trips.

- Approximately one million people visited Ohio water bodies for recreational fishing.[5] These visitors accounted for about 15.6 million fishing trips to the area. Recreational fishermen from Ohio were the most frequent users of the state water resources, representing approximately 97 percent of all visitors.

- Approximately 972,000 and 896,000 visitors used the Ohio water bodies for near-water viewing and swimming, respectively, in 1993. These visitors account for approximately 9.4 and 7.8 million viewing and swimming trips to the area. Ohio residents account for 89 percent of viewers and 93 percent of swimmers.

- Most out-of-state recreational users came from the states surrounding Ohio, such as Indiana, Michigan, and Pennsylvania.

[4] NDS collected information only on the last site visited. Its numbers do not reflect people whose last visit was to a different area, but who may have also visited an Ohio water body on a previous trip during the year. See Section 21.3 for detail on the NDS data.

[5] EPA compared the estimated number of participants with total fishing licenses issued by Ohio in 1996. Ohio issued a total of 895,770 licenses for resident and nonresident fishing. The NDS data therefore provide relatively accurate information on participation rates.

20.3.3 Commercial Fishing in Ohio

Commercial fishing is a minor activity in Lake Erie: 12 license holders share a total of 19 licenses (LECBA 2003). Commercial catch data compiled by the Great Lakes Fishery Commission are summarized in Table 20.6 (Baldwin et al. 2002).

Table 20.6: Commercial Catches for Ohio Lake Erie Waters (1990)

Fish	Catch (1990 lbs)
Yellow perch	1,559,000
Carp	1,190,000
White perch	786,000
Sheepshead	640,000
White bass	392,000
ChannelcCatfish	365,000
Quillback	134,000
Buffalo	132,000
Bullheads	59,000
Suckers	41,000
Goldfish	31,000
Gizzard shad	19,000
Lake whitefish	10,000
Rock bass	1000

Source: Baldwin et al. (2002)

Yellow perch represents about half of the dockside value for the entire commercial fishery in the Ohio waters of Lake Erie. The value of this fishery ranged from $1.3 million to $2.5 million between 1993 and 1998. Overfishing and pollution have decreased the yellow perch population throughout Lake Erie dramatically over the past 30+ years. Annual catches averaged around 20 million pounds during the 1960s and 70s. The Lake Erie Committee set the 1998 lakewide ***total allowable catch (TAC)*** quota for this species at 7.44 million pounds. The yellow perch fishery rebounded somewhat over the past couple of years, due to strong annual recruitment, strict commercial catch restrictions, and a strict creel limit of 30 fish per day for the sport angler (LECBA 2003).

20.3.4 Surface Water Withdrawals

Water resources provide a wide range of services upon being withdrawn (removed) from the water body. Once used, water can be returned to its original sources, returned to another water body, or consumed (e.g., for human drinking water). Water withdrawals from surface water averaged 9,615 mgd in 1995 (USGS 1995). The majority of this water is used in power generation, accounting for 85 percent of all surface water withdrawals. Public water supply accounts for ten percent of all withdrawals. Industrial and commercial water use account for one and four percent of the total, respectively. Water quality and quantity impairments can have substantial impacts on the key withdrawal services that water provides to a wide range of economic entities.

20.4 Surface Water Quality in Ohio

This section describes current water quality conditions in Ohio and the effects of water quality impairments on beneficial uses of Ohio's water resources. Ohio EPA assessed designated use attainment in approximately 42 percent of Ohio streams and rivers; approximately 64 percent of lakes, ponds, and reservoirs; and all of the Lake Erie shoreline (Ohio EPA, OWRI, 1996). The OWRI report summarizes the results of this assessment. This report provides information on designated use support by water type and use designation, identifies major pollutant/stressors that affect the quality of surface water bodies and prevent designated use attainment, and lists major sources of impairment. The following three sections summarize findings from the 1996 OWRI report.

20.4.1 Use Attainment in Streams and Rivers in Ohio

Most water bodies are designated for several uses and more than one use can be impaired at a time. The most commonly occurring sole impairment in fresh water bodies is to aquatic life support. The Ohio EPA used an ecosystem approach that relies on various tools to determine aquatic life use attainment. Water chemistry, physical and habitat assessment, and direct sampling of biota all contribute to determine whether a water body meets an attainment status. Field data yield biological indices that eventually determine a final attainment score.

Ohio EPA assessed 6,560 perennial river miles for aquatic life use attainment. Of the 6,560 river miles assessed for aquatic life use:

- 38.5 percent (2,536 miles) are in full attainment (i.e., all water quality indicators meet criteria for specific water bodies);
- 10.8 percent (708 miles) are in full attainment, but are threatened by pollution and other sources;
- 23.3 percent (1,528 miles) are in partial attainment (i.e., one of two, or two water quality indicators do not meet criteria); and
- 27.4 percent (1,797 miles) are in non-attainment (i.e., no criteria are met or the river experiences a severe toxic impact).

Fecal coliform bacteria counts determine recreational use attainment. Such counts are less stringent for Secondary Contact Recreation than for Primary Contact Recreation. Ohio EPA has assessed 2,402 river miles for recreation use since 1988 (Ohio EPA, OWRI, 1996). Of the 2,402 river miles assessed for recreation use:

- 57 percent (1,370.3 miles) of the sampled rivers and streams are in full attainment (i.e., a water body meets all chemical criteria for recreational use and human contact);
- 19.7 percent (474.1 miles) are in partial attainment (i.e., a water body only partially meets human contact criteria); and
- 23.2 percent (557.4 miles) are in non-attainment (i.e., a water body fails to meet human contact criteria).

20.4.2 Lake Erie and Other Lakes Use Attainment

Lake Erie, which has a history of pollution problems, currently has fish consumption advisories for carp and channel catfish (Ohio DNR, 1999). Ohio EPA assesses Lake Erie as having partial use attainment for aquatic life and fish consumption, and full attainment for recreation.[6] Ohio EPA used parameters specified by the ***Ohio EPA Lake Condition Index (LCI)*** to develop use attainment for other lakes. Only approximately two percent of all lakes are in full use attainment for aquatic life, recreation, and fish consumption. Approximately 82, 50, and 53 percent are in full attainment for aquatic life, recreation, and fish consumption, respectively, but are threatened by pollution for these categories. High percentages of lake acres are in partial attainment for recreation (38.8 percent) and public supply (43.8 percent) use designations. Table 20.7 shows use attainment for Lake Erie and other lakes, ponds, and reservoirs.

[6] Further methodologies to better assess use attainment in Lake Erie are still under development by the Ohio EPA.

Table 20.7: Use Attainment Summary for Lake Erie ane Other Lakes									
Use Category	% of Total Units Assessed	Full Attainment		Full Attainment, Threatened		Partial Attainment		Non-Attainment	
	%	Units	%	Units	%	Units	%	Units	%
Lake Erie (Unit: Shore Miles)[a]									
Aquatic Life (EWH)	100					236	100		
Recreation	100	231	98			5	2		
Fish Consumption	100					236	100		
Lakes, Ponds, & Reservoirs (Unit: Acres)									
Aquatic Life (EWH)	64.7	1,651	2.2	63,174	82.2	10,686	13.9	1,302	1.7
Recreation (PCR)	64.4	1,392	1.8	38,499	50.3	29,793	38.9	6,582	9.0
Public Water Supply	64.1	1,301	1.7	40,846	53.6	33,365	43.8	673	0.9

[a] Assessments are based on unit of measure presented in parentheses.

Source: Ohio EPA, OWRI 1996.

20.4.3 Causes and Sources of Use Non-Attainment in Ohio

Ohio EPA assessed the causes and sources of impairment to Ohio surface waters and examined trends in major causes and sources from previous assessment cycles. The following discussion summarizes findings from the 1996 OWRI report (Ohio EPA, 1996).

a. Causes

Causes are the agents responsible for damage and threats to aquatic life. The major causes of impairment in Ohio surface waters include:

- organic enrichment/low DO,
- habitat modifications,
- siltation,
- flow alteration,
- nutrients, and
- metals.

Ohio EPA examined trends in these major causes from previous assessment cycles through 1996. They found that point source-related causes declined, while non-point sources became major contributors. Ohio EPA concluded that this trend "reflects the relative effectiveness of the programs to control point sources compared to general lack of measures to control many [non-point sources]" (Ohio EPA, OWRI, 1996).

Organic enrichment, which alters DO levels and affects aquatic communities, is the main cause of impairment in Ohio's rivers and streams. Inadequate wastewater treatment from municipal and industrial point sources account for most of this impairment. Metals are a major cause of impairment to approximately 226 river miles, a moderate cause of impairment to 179 river miles, and a minor cause of impairment or threat to 165 river miles.

Nutrients, resulting mostly from agricultural non-point sources, are the main cause of impairment in lakes. Metals are a major cause for impairment in approximately 250 acres of Ohio's lakes, ponds, and reservoirs, and form the main cause of impairment in Lake Erie, the major water resource in Ohio (90 percent of the surface water volume). Highly developed areas bordering the lake contribute urban runoff, along with discharges from industrial and municipal sources. Other causes of impairment in Lake Erie include ***priority organics***, DO, and nutrients.[7]

b. Sources

Sources are the origins of the agents responsible for damage and threats to water resources. The major sources of impairment to Ohio surface waters include:

- municipal and industrial discharges,
- hydromodification,
- agricultural runoff,
- urban runoff, and
- mining.

Point source-caused impairment has declined over time, while that from non-point sources, such as agricultural and urban runoff, has increased. Point sources remain a major source of impairment in almost 900 miles, or 25 percent, of Ohio's affected rivers and streams. Point sources are the major source of impairment for Lake Erie. They form a major source of impairment for 24 shore miles, and a moderate source of impairment for an additional 281 shore miles of Lake Erie. In addition, point sources adversely affect 1,678 lake acres.

Non-point sources related to agricultural and urban runoff form the major source of impairment for some 9,000 acres, or two-thirds of Ohio's lakes, ponds, and reservoirs. In addition, 46 Lake Erie shore miles list non-point sources as their major impairment source.

20.5 Effects of Water Quality Impairments on Water Resource Services

Water resource services are negatively affected by pollutants that impair the aquatic ecosystems. Certain pollutants can adversely affect aquatic species directly by increasing species morbidity and/or impairing reproductive success, or indirectly by adversely altering food chain interactions. These direct and indirect impacts can change quantity and type of fish and other species in the aquatic ecosystem. In the worst case scenario, an impaired ecosystem no longer supports any aquatic life. High pathogen counts or excessive eutrophication in water bodies that are suitable for swimming may force swimmers to go elsewhere or forego swimming altogether. Any aesthetic degradation decreases the value of each individual's recreational experience. In severe cases, the affected water bodies become unsuitable for recreation. Water quality impairments also increase the cost of treating water to meet drinking water standards.

This section details the effects of water quality impairments on in-stream services provided by Ohio's water resources.

20.5.1 Effect of Water Quality Impairment on Life Support for Animals and Plants

Deficiencies in water quantity and quality can impair the health of aquatic ecosystems. In worst case scenarios, the ecosystem may no longer support aquatic life at all. The major causes of water quality impairment in Ohio include high ***biological oxygen demand (BOD)*** from organic enrichment, habitat and flow alterations, nutrients, ***siltation*** and ***turbidity***, ***metals***, ***pH***, ***ammonia***, and priority organics. Habitat, flow alterations, and thermal discharges are unrelated to MP&M effluents and are not discussed here. MP&M effluents contribute to the remaining major causes of water quality impairment, with the ecological effects outlined below.

a. BOD/COD

BOD and ***chemical oxygen demand (COD)*** are two methods to determine the oxygen requirements of pollutants in wastewater. Low oxygen level is the primary cause of impairment in Ohio's rivers and streams and a major source of

[7] Major, moderate, and minor impacts refer to the high, moderate, and slight magnitude codes specified by the U.S. EPA for the 301(b) report.

impairments in Ohio's lakes. When bacteria decompose excess organic matter, they consume DO in surface waters. Oxygen is needed to chemically (abiotically) oxidize the pollutants present in wastewater. When too much oxygen is needed to oxidize pollutants, hypoxic (oxygen deficient) or anoxic (oxygen depleted) conditions result. Sources of high oxygen demand include effluents from municipal treatment plants and certain industries, and runoff from feedlots or farms. Another source is ***eutrophication*** caused by excessive nutrient input. The nutrients stimulate algal blooms. Bacteria consume the algae when they die, decreasing DO in the water column. DO is a critical variable for fish and invertebrate survival. If oxygen concentrations drop below a minimum level, organisms suffocate and either move out or die (EPA, 1986). This effect can drastically reduce the amount of useable aquatic habitat.

b. Nutrients

Nutrients are the leading causes of impairment in Ohio lakes and comprise one of the major causes of impairment in rivers, streams, and Lake Erie. The overabundance of nitrogen and phosphorus is one of the most documented forms of aquatic ecosystem pollution. Although both compounds are essential nutrients for phytoplankton (free-floating algae) and periphyton (attached algae), which form the base of the aquatic food web, too much nutrient input overstimulates primary productivity and results in eutrophication. The impact of these compounds has contributed significantly to water quality decline in the United States (EPA, 1992). Phosphorus is a limiting nutrient in most freshwater systems (Wetzel, 1983), whereas nitrogen is typically limited in estuarine and marine systems.

In freshwater, excess phosphate (PO_4) has been linked to eutrophication and nuisance growth of algae and aquatic weeds (Wetzel, 1983), even though direct toxicity to fish and other aquatic species is not a major concern. DO in the water column decreases, however, when algae and other aquatic plants die off, and certain toxins may be produced, both of which can contribute to fish kills.

c. Siltation and turbidity

Siltation and turbidity are the third leading causes of impairments in Ohio rivers and lakes, except Lake Erie. Siltation is the most important factor in surface water degradation in the U.S. (EPA, 1992). Major sources include urban and stormwater runoff, mining and logging activities, and runoff from plowed fields (EPA, 1992). All these inputs create cloudy water with increased turbidity and decreased visibility and light penetration. High primary productivity by phytoplankton following excessive nutrient input can also increase turbidity. Excess suspended matter decreases the amount of light penetrating the water column, which can reduce primary productivity. This turbidity can eliminate or displace fish species requiring clear water to live, feed, or reproduce.

d. Metals

Metals are the leading cause of impairment in Lake Erie and comprise one of the major causes of impairment in inland lakes and rivers. Metals are naturally-occurring inorganic constituents of the earth's crust. Priority pollutant metals commonly found in the aquatic environment include antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium and zinc (EPA, 1998a). These compounds enter the aquatic environment via urban stormwater runoff, industrial and municipal effluents, and atmospheric deposition. As a group, metals can be highly toxic: ***water quality criteria (WQC)*** for acute toxicity range from around 1,100 ***µg/l*** (chromium VI in saltwater) to around 1 µg/l (mercury in freshwater); WQC for chronic toxicity range from 120 µg/l (zinc in freshwater) to <1.0 µg/l (mercury in salt- and freshwater) and are therefore an order of magnitude lower (EPA, 1998a).

Once metals reach the aquatic environment, they tend to associate with organic and inorganic particulates in the water column. Sediments become long-term sinks for metals, which accumulate in the bottom. Metals can enter the food chain when ingested by benthic invertebrates or other burrowing organisms. Most metals have ***bioconcentration factors (BCFs)*** ranging from 100 to 10,000 and can therefore bioaccumulate in aquatic organisms. A few, including selenium, lead, and mercury, may reach hazardous levels in fish or wildlife receptors and result in avian developmental or neurological abnormalities.

e. Organic chemicals

Priority organics are the second most frequent cause of impairment in Lake Erie and comprise one of the major causes of impairment in rivers and streams. Thousands of different compounds exist as organic chemicals, including petroleum hydrocarbons and myriad industrial chemicals. They enter the aquatic environments via municipal and industrial effluents, stormwater runoff, contaminated groundwater, atmospheric deposition, illegal dumping, or accidental releases. Aquatic toxicities vary by orders of magnitude depending on the compound. Factors influencing toxicity and long-term ecological effects include water solubility, volatility, biodegradation potential, and bioaccumulation potential.

Excessive amounts of organic chemicals degrade surface water quality by causing acute or (more typically) chronic toxicity. This toxicity impairs growth, development, and/or reproductive success in fish and aquatic invertebrates. Persistent and low water-soluble organic chemicals accumulate in sediments and are taken up into local aquatic food chains. They can reach dangerous concentrations in fish and avian receptors, resulting in reproductive failures or other avian health effects.

f. pH

Approximately 180 river miles are pH-impaired in Ohio. pH is a measure of acidity. Acid reaches surface waters via atmospheric deposition ("acid rain"), industrial effluents, and leachates from mine **overburdens** or spoils. Acidity by itself is a key variable shaping aquatic communities: it is a toxicant in its own right but also controls metal solubility, and the toxicity of several metals and ammonia.

Aquatic species vary widely in their sensitivity to pH: the most sensitive vertebrate and invertebrate species die off when average pH ranges between 6.0 and 6.5. Most fish species are eliminated when pH reaches 5.0. Only a few can survive at pH 4.5 (U.S. EPA, 1999). Macro invertebrates exhibit the same pattern, except that hardy species can survive down to a pH of about 3.5.

g. Ammonia

Large amounts of ammonia enter lakes and rivers via wastewater treatment plants and industrial effluents, atmospheric deposition, and non-point source surface runoff. Approximately 150 river miles in Ohio are ammonia-impaired. This compound, unique among regulated pollutants, is also produced naturally inside fish as a metabolic waste product. Excess ammonia usually diffuses rapidly out of the blood stream and into the surrounding water via the gills. High concentrations of external ***un-ionized*** ammonia (NH_3) reduce or reverse this diffusive gradient and allow ammonia to build up to toxic levels inside the organism (EPA, 1998c).

Ammonia in surface water exists in two major forms: un-ionized ammonia (NH_3), which is highly toxic to fish or invertebrates, and ammonium ion (NH_4^+), which is much less toxic. Which form prevails depends mainly upon the pH level; temperature and ionic composition play a smaller role. EPA calculated a WQC that becomes more severe with decreasing acidity. For example, the acute criteria for surface waters containing salmonids equals 36.7 mg/l at pH=6.0 but only 2.14 mg/l at pH=8.5. For surface waters without salmon, the acute criteria for the same pH equal 55.0 mg/l and 3.2 mg/l, respectively (EPA, 1998c).

20.5.2 Effect of Water Quality Impairment on Recreational Services

Healthy surface waters are essential to support a diversity of recreational uses, including viewing and other near-water activities. Industrial or other human activities impair surface water quality. Certain metals and chlorinated compounds can bioaccumulate in aquatic food chains and reach unhealthy levels in carnivorous fish or shellfish. Health advisories to limit or avoid their consumption may result. High concentrations of toxic compounds can also lead to human contact advisories. The release of untreated or poorly treated sewage can cause high levels of pathogenic bacteria in water and result in swimming advisories or beach closures. All of these actions limit the full use of surface waters and can have significant local economic impacts.

a. Fish consumption advisories

In 1997, the Ohio Department of Health ***(ODH)*** issued a statewide fish consumption advisory to protect women of childbearing age and children six years or younger against mercury's neurological and developmental effects. The advisory, which applies only to these two population groups, recommended that these women and children eat no more than one meal per week of any fish caught in Ohio waters. The advisory covers all state waters because most of the mercury measured in fish tissues originates from region-wide fossil fuel combustion processes. The mercury reaches surface waters via atmospheric deposition on the surrounding landscape (Ohio DNR, 1999).

Since 1983, the ODH has developed numerous water body-specific fish consumption advisories for approximately 174 water body segments (rivers and lakes) and Lake Erie. These water bodies represent a relatively small fraction of Ohio's 5,000 discrete water body segments, as determined by Ohio EPA. The contaminants of greatest concern include ***polychlorinated biphenyls (PCBs)***, mercury, ***polycyclic aromatic hydrocarbons (PAHs)***, lead, organometallics, Mirex, phthalate esters, Chlordane, and hexachlorobenzene. Of these, four mercury, PAHs, lead, and phthalates are included on the MP&M list of ***pollutants of concern (POCs)***. As a group, these contaminants are generally characterized as lipophilic (i.e., fat loving), resistant to biological degradation or cellular metabolism, and toxic. Once they reach surface water, they concentrate in sediments and bioaccumulate or biomagnify through aquatic food chains. These compounds can linger for decades in aquatic systems.

The kind of sports or recreational fish species affected by the consumption advisories varies by water body segment. More than 23 different species are covered by advisories, including walleye, common carp, sauger, saugeye, white crappie, freshwater drum, and various species of bass, perch, catfish, salmon, trout, suckers, and sunfish. Restrictions vary depending on the pollutant, the fish species concerned, and the concentrations measured in edible tissues. The ODH developed maximum recommended rates of fish consumption that include outright consumption bans, one meal every two months, one meal a month, or one meal a week. The same water body segments can commonly have different advisories for different fish species (Ohio DNR, 1999).

b. Contact advisories

The ODH also issued human contact advisories for nine water body segments in Ohio located on the Black River, Little Scioto River, Mahoning River, the middle fork of the Little Beaver Creek, and the Ottawa River. Swimming or wading is prohibited due to the presence of high levels of PAHs, PCBs, Mirex, phthalate esters, and/or Chlordane. Of these, PAHs and phthalates are included on the list of MP&M POCs. Fish consumption advisories also cover all of these segments (Ohio DNR, 1999).

c. Beach closures

Beach closures typically occur during the summer months when high levels of fecal coliform bacteria or other disease-causing organisms (e.g., *Escherichia coli*) proliferate in surface waters. Such waters can become contaminated from several sources, including: agricultural runoff, sewer overflows, boating wastes, and poor hygienic practices by some bathers. Excessive levels of indicator pathogens in surface waters can indicate a serious threat to human health and may cause health departments to post warnings, restrict access, or forbid swimming altogether. The MP&M regulation is not expected to reduce beach closures during summer months.

Numerous public bathing beaches dot Ohio's 262-mile shoreline along Lake Erie. The ODH has developed a composite metric based on *E. coli* counts in surface waters at 11 selected beaches along Ohio's north coast. The metric tracks the average number of days that swimming advisories are posted at the 11 beaches for a 15 week period beginning around Memorial Day and continuing through Labor Day. The most recent data available show that the 11 beaches were under advisement an average of 21 days during the summer months (minimum of 0 days and maximum of 49 days) in 1996.

The ODH developed a 4-tiered scale to score and track the average number of days that the 11 public beaches are under advisement from one year to the next. Between 1990 and 1996, the average (based on a five-year running average) number of beach advisories scored in the "fair" category consistently, meaning that the beaches were under advisement between 20 and 30 days in the summer (State of Ohio, 1998).

Ohio's lakes, ponds, and reservoirs (excluding Lake Erie) yielded no quantitative data on beach closures. The 1996 Ohio Water Resource Inventory of Public Lakes, Ponds and Reservoirs provides a breakdown of the portion of Ohio's 446 public lakes that are threatened or impaired as a result of high levels of fecal coliform bacteria.

20.6 Presence and Distribution of Endangered and Threatened Species in Ohio

Many factors can affect the survival of ***endangered and threatened (E&T)*** species. Some factors are species-specific; others result from one or more anthropogenic stressors. Inherent vulnerability factors include narrow geographic distribution, slow reproductive rates, or requirements for large areas. Major anthropogenic stressors include intentional taking (e.g., fishing), incidental taking, physically altering habitat (e.g., converting wetlands into agricultural land), water pollution, and introducing alien species. A single stressor or a set of stressors can contribute to a species' decline or extinction. Previous studies reported that more than 40 percent of endangered aquatic species were affected by five or more environmental stressors, and only seven percent of federally-listed species had a single threat to their survival. Although stressors seldom act alone, water pollution is one of the major hazards to E&T aquatic species, cited as responsible for the decline of 19 (54 percent) out of 35 E&T fish species in Ohio (Ohio DNR, 1998).

The following sections provide an overview of E&T species found in Ohio, their distribution, and the major hazards threatening their survival. Species discussed below include those listed under both the federal ***Endangered Species Act*** (50 CFR Part 17) and the Ohio Department of Natural Resources' ***(DNR)*** Division of Natural Areas and Preserves. The MP&M regulation concentrates on water-related benefits; these sections therefore describe only those species associated with aquatic environments.[8] The DNR list includes 90 E&T species with a total of 1,227 observations throughout Ohio. "Observations" refers to locations where species were observed; most species have multiple observations. This analysis includes observations spanning the years 1980 to 1988.

20.6.1 E&T Fish

E&T fish inhabit almost every major water body in Ohio, including Lake Erie and the Ohio River and its tributaries. The Ohio DNR lists 35 total state-listed E&T fish species, of which 13 are threatened and 22 endangered. The list includes only one federally-listed species, the scioto madtom.

Of the total E&T fish, approximately 12 species use Lake Erie as a possible habitat and nine use the Ohio River. Most of the species listed live in riverine habitats. Approximately 28 species were identified in a river system in Ohio, including the Ohio, Scioto, Muskingham, Miami, Walhondig, and Maumee River systems. MP&M facilities are found on all these major river systems.

The DNR lists 384 observations of E&T fish in Ohio, of which 240 observations of 30 different species have been reported since 1980. Figure 20.2 maps the observations of E&T fish in Ohio and shows the extent to which these observations were reported in the state. Multiple observations can occur for a single species. In southern Ohio, most observations come from the Muskingham and Scioto River systems and the Ohio River. Most observations in northern Ohio came from Lake Erie tributaries or the lake itself.

In addition to water pollution, cited above as major hazard to E&T aquatic species, other major hazards to E&T fish include siltation and impoundments. Approximately two-thirds of E&T fish species are threatened by siltation, and 17 percent are threatened by impoundments or dams. MP&M regulations can improve affected ecosystems or habitats by reducing discharges from MP&M facilities. These improvements can then help reduce siltation and restore some of the E&T fish populations.

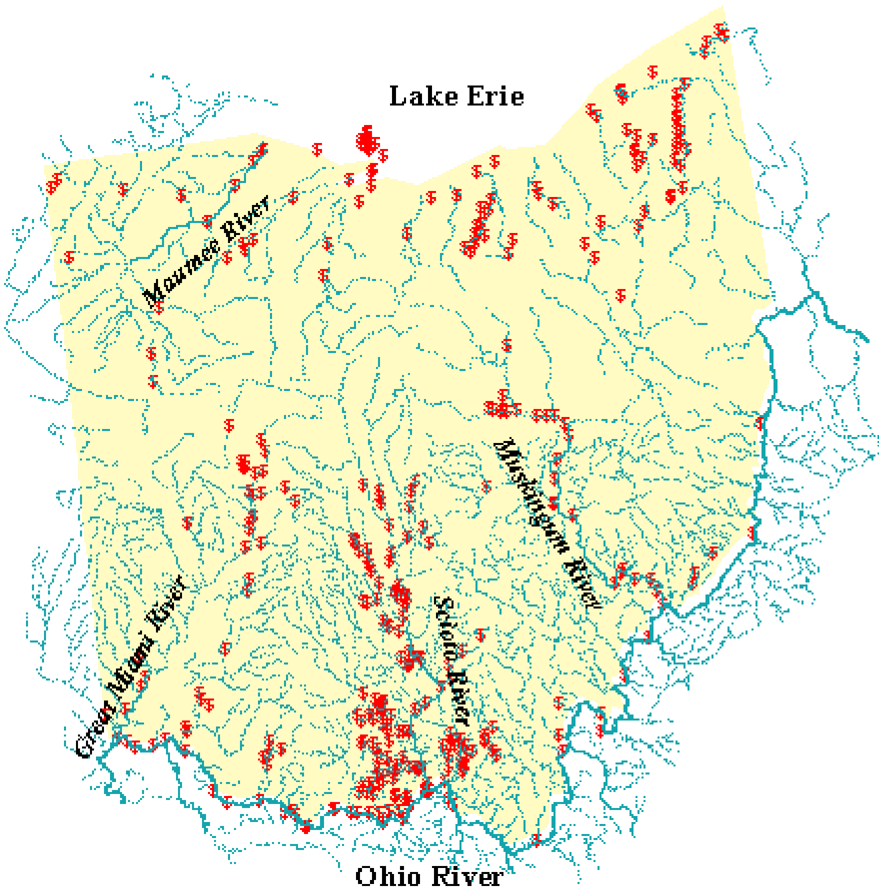
Many obscure E&T fish species have a pure existence value. Some E&T species, like brook trout and lake sturgeon, have high potential for consumptive uses. Restoring their populations and those of other commercial and recreational fish species may enhance recreational fishing opportunities. Table 20.8 lists E&T fish in Ohio, their habitat locations, and the cause for their E&T listing. The table lists species alphabetically by scientific name.

20.6.2 E&T Mollusks

Mollusks yield the largest number of reported observations of aquatic E&T species in Ohio, representing 48 percent of the total 1,227 observations. The Ohio DNR lists 29 E&T mollusk species, four threatened and 25 endangered. Of these, five mollusk species are on the federal endangered species list: catspaw, clubshell, fanshell, white catspaw, and pink mucket. Ohio's E&T mollusks concentrate in five major areas: Lake Erie and the Grand River tributary, Scioto River and Big Arby tributary, Muskingham River, Little Miami River, and the Ohio River. E&T mollusk populations reside mostly along the mainstems of large rivers and in Lake Erie, but are also found in the St. Joseph, Sandusky, and Cuyahoga Rivers.

[8] "Aquatic species" were identified by the Ohio Department of Natural Resources, Division of Natural Areas and Preserves. These species include any species that are "closely associated with aquatic habitats through their breeding or feeding requirements."

Figure 20.2: E&T Fish Observances in Ohio[a]
(1980-1997)



[a] Each $ represents an observance.

Source: U.S. EPA analysis.

20.6.3 Other Aquatic E&T Species

Improved water quality resulting from the MP&M regulation may also benefit other aquatic E&T species. Unlike fish and mollusks, whose primary habitat is a surface water body at all times, these species may use surface water-related habitats only for breeding or feeding. Improved water quality may benefit these populations indirectly by enhancing the quality and quantity of aquatic biological resources.

Other aquatic-associated E&T species of Ohio include:

- Birds ten state-listed species, one threatened and nine endangered, include one federally-listed threatened species, the bald eagle. The state-listed species include: American and least bitterns, common and black terns, yellow- and black-Crowned night-herons, king rail, osprey, and snowy egret. These species are observed mostly along the Lake Erie coast. The bald eagle is observed mostly in Ohio's northeast corner.

- Amphibians three state-listed endangered species: blue-spotted salamander, observed in the very northwest section of the state along small streams and near the Maumee River; eastern spadefoot, found near the Ohio and Muskingham Rivers; and eastern hellbender, observed along the Muskingham and Scioto River systems and tributaries of the Ohio River.

- Reptiles two species: the copperbelly water snake, a state-listed endangered and federally-listed threatened species found in lakes and ponds in the northwest corner of Ohio; and the Lake Erie water snake, state-listed as threatened and a proposed threatened species for the federal list, found only along the edges of the Lake Erie islands.

- Mammals the river otter is state-listed as endangered. Sparse observations of the animal come from various small creeks and lakes in the eastern part of Ohio.

- Crustaceans the state-listed endangered Sloan's crayfish has been observed in several small tributaries of the Great Miami River system.

- Insects nine state-listed species, one threatened and eight endangered, are reported throughout the state.

Table 20.8: Endangered and Threatened Fish Species of Ohio

Common Name	Scientific Name	Number of Observations	Last Observed	Federal Status	State Status	Habitat	Causes for Listing
Lake sturgeon	*Acipenser fulvescens*	3	1979		E	Lake Erie, spawning in larger rivers such as Maumee and Auglaize	Pollution and dams
Longnose sucker	*Catostomus catostomus*	1	1950		E	Lake Erie	Pollution creating low oxygen levels
Rosyside dace	*Clinostomus funduloides*	53	1997		T	Small, upland streams of Teays and Little Scioto River systems	Runoff and siltation
Cisco	*Coregonus artedi*	1	1976		E	Lake Erie	Pollution and overfishing
Blue sucker	*Cycleptus elongatus*	2	1985		E	Ohio River and lower reaches of large tributaries	Pollution, dams, increased turbidity and siltation
Lake chubsucker	*Erimyzon sucetta*	28	1994		T	Lakes (not Erie) and larger streams	Increased turbidity and siltation
Bluebreast darter	*Etheostoma camurum*	19	1995		T	Scioto and Muskingham River systems, large streams	Pollution and siltation
Spotted darter	*Etheostoma maculatum*	8	1992		E	Large streams of Muskingham and Scioto systems	Pollution and siltation
Tippecanoe darter	*Etheostoma tippecanoe*	11	1994		T	Muskingham and Scioto River systems	
Tonguetied minnow	*Exoglossum laurae*	16	1996		T	Great Miami River system	Undetermined, likely pollution and siltation
Western banded killifish	*Fundulus diaphanus menona*	9	1994		E	Lake Erie and larger tributaries	Siltation
Goldeye	*Hiodon alosoides*	16	1989		E	Ohio River and lower reaches of large tributaries	Pollution
Mississippi silvery minnow	*Hybognathus nuchalis*	1	1983		E	Ohio River and tributaries	Siltation
Ohio lamprey	*Ichthyomyzon bdellium*	4	1992		E	Ohio River and lower reaches of large tributaries	Pollution and siltation
Northern brook lamprey	*Ichthyomyzon fossor*	25	1992		E	Small streams, tributaries of Grand and Scioto rivers	Pollution, siltation, and dams
Mountain brook lamprey	*Ichthyomyzon greeleyi*	6	1993		E	Mahoning River and tributaries	Pollution, siltation, and dams
Silver lamprey	*Ichthyomyzon unicuspis*	40	1993		T	Lake Erie and larger tributaries	Pollution, siltation, and dams
Blue catfish	*Ictalurus furcatus*	1	1987		E	Scioto River	
Spotted gar	*Lepisosteus oculatus*	1	1978		E	Lake Erie	Siltation and dredging

Table 20.8: Endangered and Threatened Fish Species of Ohio

Common Name	Scientific Name	Number of Observations	Last Observed	Federal Status	State Status	Habitat	Causes for Listing
Shortnose gar	*Lepisosteus platostomus*	9	1981		E	Scioto River and tributaries	Pollution and siltation
Speckled chub	*Macrhybopsis aestivalis*	1	1990		E	Ohio and Muskingham rivers, large rivers	Pollution and siltation
Greater redhorse	*Moxostoma valenciennesi*	12	1989		T	Maumee river system, large streams	Pollution and siltation
Popeye shiner	*Notropis ariommus*	4	1993		E	Extirpated from Ohio, creeks and small rivers of Maumee system	Siltation
Bigeye shiner	*Notropis boops*	22	1995		T	Great Miami River and Ohio River systems, upland streams	Siltation and impoundments
Bigmouth shiner	*Notropis dorsalis*	16	1994		T	Black and Rocky River systems, brooks and small streams	Competition with silver minnow
Blackchin shiner	*Notropis heterodon*	2	1983		E	Lake Erie and other lakes	Increased turbidity and siltation
Blacknose shiner	*Notropis heterolepis*	7	1983		E	Lake Erie and other lakes	Siltation
Mountain madtom	*Noturus eleutherus*	11	1991		E	Ohio River tributaries, larger streams and rivers	Pollution and siltation
Northern madtom	*Noturus stigmosus*	10	1989		E	Muskingham, Little Miami, Walhondig Rivers	
Scioto madtom	*Noturus trautmani*	1	1957	E	E	Big Darby Creek, tributary of Scioto	Pollution and siltation
Pugnose minnow	*Opsopoeodus emiliae*	6	1982		E	Lakes, canals, streams, and Lake Erie	Increased turbidity and siltation
Channel darter	*Percina copelandi*	18	1991		T	Lake Erie and Ohio River	Siltation
River darter	*Percina shumardi*	8	1989		T	Lake Erie and larger tributaries of Ohio River	Pollution and siltation
Paddlefish	*Polyodon spathula*	11	1996		T	Ohio River tributaries, larger streams and rivers	Pollution and siltation
Brook trout	*Salvelinus fontinalis*	1	1997		T	Tributaries of Lake Erie	Habitat destruction - timbering and non-native species

Source: Division of Natural Areas and Preserves, Ohio Department of Natural Resources, Natural Heritage Program 1998.

GLOSSARY

ammonia: a compound of nitrogen and hydrogen (NH_3). It is a colorless, pungent gas.

biological oxygen demand (BOD): the amount of dissolved oxygen consumed by microorganisms as they decompose organic material in polluted water.

bioconcentration factors (BCFs): indicators of the potential for chemicals dissolved in the water column to be taken up by aquatic biota across external surface membranes, usually gills.

biotic: pertaining to the characteristics of a naturally occurring assemblage of plants and animals that live in the same environment and are mutually sustaining and interdependent.

chemical oxygen demand (COD): the amount of oxygen consumed in the complete chemical oxidation of matter, both organic and inorganic, present in polluted water.

Coldwater Habitat (CWH): a designation assigned to a water body based on the potential aquatic assemblage.

dissolved oxygen (DO): oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced waste treatment are generally designed to ensure adequate DO in waste-receiving waters. (http://www.epa.gov/OCEPAterms/dterms.html)

endangered and threatened (E&T): animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (i.e., man-caused) or other natural changes in their environment. The Endangered Species Act contains requirements for declaring a species endangered.

Endangered Species Act: federal legislation enacted in 1973 that protects animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic or other natural changes in their environment. For a species to be protected under this act it must be "listed" as either an "endangered" or "threatened" species.

eutrophication: process by which bodies of water receive increased amounts of dissolved nutrients, such as nitrogen and phosphorus, that encourage excessive plant growth and result in oxygen depletion.

Exceptional Warmwater Habitat (EWH): the aquatic life use designed to protect aquatic communities of exceptional diversity and biotic integrity. Such communities typically have a high species richness; often include strong populations of rare, endangered, threatened, and declining species; and/or are exceptional sport fisheries.

existence services: services that are not linked to current uses of water bodies. They arise from the knowledge that species diversity or the natural beauty of a given water body is being preserved.

in-stream services: water use taking place within the stream channel for purposes such as life support for animals and plants, water-based recreation, hydroelectric power generation, navigation, commercial fishing, water storage, and aesthetics.

Limited Resource Waters (LRW): an aquatic life use assigned to streams with very limited aquatic life potential, usually restricted to highly acidic mine drainage streams, or highly modified small streams (<3 sq. mi. drainage area) in urban or agricultural areas with little or no water during the summer months.

Limited Warmwater Habitat (LWH): see limited resource waters.

metals: inorganic compounds, generally non-volatile (with the notable exception of mercury), that cannot be broken down by biodegradation processes. They are of particular concern due to their prevalence in MP&M effluents. Metals can accumulate in biological tissues, sequester into sewage sludge in POTWs, and contaminate soils and sediments when released into the environment. Some metals are quite toxic even when present at relatively low levels.

μg/l: micrograms per liter.

Modified Warmwater Habitat (MWH): aquatic life use assigned to streams that have irretrievable, extensive, man-induced modifications that preclude attainment of the Warmwater Habitat use, but which harbor the semblance of an aquatic community. Such waters are characterized by poor chemical quality (low and fluctuating dissolved oxygen), degraded habitat conditions (siltation, habitat simplification), and species that are tolerant of these effects.

nonconventional pollutants: a catch-all category that includes everything not classified as either a priority or conventional pollutant.

nutrients: any substance, assimilated by living things, that promotes growth. The term is generally applied to nitrogen and phosphorus in wastewater, but is also applied to other essential and trace elements. (http://www.epa.gov/OCEPAterms/nterms.html)

Ohio EPA Lake Condition Index (LCI): an ecologically-based index that aggregates results across ten ecological metrics.

Ohio Water Resource Inventory (OWRI): a biennial report to U.S. EPA and Congress required by Section 305(b) of the Clean Water Act. The report is composed of four major sections: (1) inland rivers and streams, wetlands, Lake Erie, and water program description; (2) fish tissue contaminants; (3) inland lakes, ponds, and reservoirs; and (4) groundwater.

overburdens: rock and soil cleared away before mining. (http://www.epa.gov/OCEPAterms/oterms.html)

pH: an expression of the intensity of the basic or acid condition of a liquid. Natural waters usually have a pH between 6.5 and 8.5. (http://www.epa.gov/OCEPAterms/pterms.html)

pollutants of concern (POCs): the 131 contaminants identified by EPA as being of potential concern for this rule and that are currently being discharged by MP&M facilities. EPA used fate and toxicity data, in conjunction with various modeling techniques, to identify these pollutants and assess their potential environmental impacts on receiving water bodies and POTWs. MP&M pollutants of concern include 43 priority pollutants, 3 conventional pollutants, and 86 nonconventional pollutants.

polychlorinated biphenyls (PCBs): a group of toxic, persistent chemicals that are mixtures of chlorinated biphenyl compounds having various percentages of chlorine. PCBs are industrial chemicals formerly used in electrical transformers and capacitors for insulating purposes, and in gas pipeline systems as a lubricant.

polycyclic aromatic hydrocarbons (PAHs): a class of organic compounds with a fused-ring aromatic structure. PAHs result from incomplete combustion of organic carbon (including wood), municipal solid waste, and fossil fuels, as well as from natural or anthropogenic introduction of uncombusted coal and oil. PAHs include benzo(a)pyrene, fluoranthene, and pyrene.

Primary Contact Recreation (PCR): water recreation activities requiring full human body immersion, such as swimming, diving, water skiing, and surfing.

priority organics: prority pollutants that are organic chemicals.

priority pollutants: 126 individual chemicals that EPA routinely analyzes when assessing contaminated surface water, sediment, groundwater, or soil samples.

random utility model (RUM): a model of consumer behavior. The model contains observable determinants of consumer behavior and a random element.

Secondary Contact Recreation (SCR): water recreation activities requiring some direct contact with water but where swallowing of water is unlikely, such as paddling, wading, and boating.

siltation: deposition of finely divided soil and rock particles on the bottom of stream and river beds and in reservoirs.

Survey of National Demand for Water-based Recreation (NDS): a U.S. EPA survey of recreational behavior. The 1993 survey collected data on socioeconomic characteristics and water-based recreation behavior using a nationwide stratified random sample of 13,059 individuals aged 16 and over. (http://www.epa.gov/opei)

total allowable catch (TAC): amount of fish permitted to be removed under a fishery management regime in which the total catch allowed of a certain species for a fishing season has been fixed in advance.

"toxic" pollutants: refers to the 126 priority or toxic pollutants specifically defined as such by EPA, as well as nonconventional pollutants that have a toxic effect on human health or aquatic organisms.

turbidity: cloudy condition in water that interferes with the passage of light through the water column. It is caused by the presence of suspended silt or organic matter in the water body.

un-ionized: neutral form of an ionizable compound. With reference to ammonia, it is the neutral form of ammonia-nitrogen in water, usually occurring as NH_4OH. Un-ionized ammonia is the principal form of ammonia that is toxic to aquatic life. The relative proportion of un-ionized to ionized ammonia (NH^{4+}) is controlled by water temperature and pH.

Warmwater Habitat (WWH): a designation assigned to a water body based on the potential aquatic assemblage.

water quality criteria (WQC): specific levels of water quality that, if reached, are expected to render a body of water suitable for certain designated uses.

withdrawal services: services associate with water removed from the ground or diverted from a surface-water source for uses such as drinking water supply, irrigation, production and processing services, and sanitary services.

ACRONYMS

BCFs: bioconcentration factors
BOD: biological oxygen demand
COD: chemical oxygen demand
CWH: Coldwater Habitat
DO: dissolved oxygen
E&T: endangered and threatened
EWH: Exceptional Warmwater Habitat
LRW: Limited Resource Waters
LWH: Limited Warmwater Habitat
MWH: Modified Warmwater Habitat
ODH: Ohio Department of Health
DNR: Ohio Department of Natural Resources
LCI: Ohio EPA Lake Condition Index
OWRI: Ohio Water Resource Inventory
POCs: pollutants of concern
PCBs: polychlorinated biphenyls
PAHs: polycyclic aromatic hydrocarbons
PCR: Primary Contact Recreation
RUM: random utility model
SSH: Seasonal Salmonid Habitat
SCR: Secondary Contact Recreation
NDS: Survey of National Demand for Water-based Recreation
TAC: total allowable catch
WWH: Warmwater Habitat
WQC: water quality criteria

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Chapter 21: Modeling Recreational Benefits in Ohio with a RUM Model

INTRODUCTION

The recreational benefits analysis outlined in this chapter focuses on Ohio as a case study of the MP&M regulation's expected benefits. EPA combined water quality modeling and a ***random utility model*** of consumer behavior ***(RUM)*** to assess how changes in water quality from the MP&M regulation will affect consumer valuation of water resources for recreational uses. The RUM analysis provides a framework for estimating the effect of ambient water quality and other site characteristics on the total number of trips taken for different water-based recreation activities and the allocation of these trips among particular sites.

The Agency used this case study to address limitations inherent in the benefits transfer method used in the analysis of recreational benefits at the national level (see Chapter 15 for detail). The RUM model assesses water quality characteristics directly affected by the MP&M regulation, such as presence of ***ambient water quality criteria (AWQC)*** exceedances and nonconventional nutrient ***Total Kjeldahl Nitrogen (TKN)*** concentrations and their effect on recreation behavior. The direct link between the water quality measures included in the RUM model and the water quality measures affected by the regulation, as well as the site specific nature of the analysis reduce uncertainty in benefit estimates. In general, RUM models are well-regarded in the economic literature and when these models are appropriately applied, the results are thought to be quite reliable.

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Benefits transfer results are subject to uncertainty because water quality changes evaluated in available recreation demand studies are only roughly comparable with water quality measures considered in regulatory development. This case study analysis improves upon previous recreation demand studies that focused mainly on directly observable water quality effects, e.g., designated use support (i.e., whether a water body supports fishing), the presence of fish advisories, an oil sheen, or eutrophication. The Ohio case study includes unobservable water quality effects as well. The MP&M regulation affects a broad range of pollutants, many of which are toxic to human and aquatic life but are not directly observable (i.e., ***priority*** and ***nonconventional pollutants***. These unobservable toxic pollutants degrade aquatic habitats, decrease the size and abundance of fish and other aquatic species, increase fish deformities, and change watershed species composition. Water quality changes (i.e., changes in toxic pollutant concentrations) affect consumers' water resource valuation for recreation, even if consumers are unaware of changes in ambient pollutant concentrations.

This study allows for a more complete estimate of recreational benefits from reduced discharges of MP&M pollutants. In addition to estimates of recreational benefits from reduced frequency of AWQC exceedances, the Ohio case study evaluated changes in the water resource values from reduced discharges of TKN. The analysis also values additional recreational uses not addressed in the national analysis, such as swimming.

The study used data from the ***National Demand Survey for Water-Based Recreation (NDS)***, conducted by U.S. EPA and the National Forest Service, to examine the effects of in-stream pollutant concentrations on consumer decisions to visit a particular water body (U.S. EPA, 1994).

21.1 METHODOLOGY

21.1.1 Overview

The Ohio study combines direct simulation and ***inferential analyses*** to assess how changes in water quality will affect consumers' valuation of water resources.

The direct simulation analysis component estimates baseline and post-compliance *water quality* at recreation sites actually visited by the surveyed consumers *and* all other sites within the ***consumers' choice set***, visited or not.

The inferential analysis component, a RUM analysis of consumer behavior, estimates the effect of ambient water quality and other site characteristics on the total number of trips taken for different water-based recreation activities and the allocation of these trips among particular recreational sites. The RUM analysis is a ***travel cost model (TCM)***, in which the cost to travel to a particular recreational site represents the "price" of a visit.

The main advantage of the RUM model is inclusion of the effect of substitute sites on site values. For any particular site, assuming that it is not totally unique in nature, the availability of substitutes makes the value for that site lower than it would be without available substitutes.

EPA modeled two consumer decisions:

- how many water-based recreational trips to take during the recreational season (the ***trip participation model***); and
- conditional on the first decision, which recreation site to choose (the ***site choice model***).

The econometric estimation proceeded in two steps, each corresponding to the above decisions. The Agency estimated these decisions in reverse order (i.e., EPA modeled the second decision, site choice, first).

- *Modeling the Site Choice Decision.* Assuming that a consumer decides to take a water-based recreation trip, EPA estimated the likelihood that the consumer will choose a particular site as a function of site characteristics, the price paid per site visit, and household income. A consumer weighs the attributes for various "choice set" sites against the travel costs to each site. These travel costs include both the cost of operating a vehicle and the opportunity costs of time spent traveling. The consumer then weighs the value given to the site's attributes against the cost of getting to the site when making a site selection. The site choice model estimates how recreational users value access to specific sites, and estimates per trip economic values for changes in water quality at recreational sites in the study area.

  EPA estimated the site choice model using a two-level ***nested multinomial logit (NMNL)*** model, which groups sites with similar characteristics. The nested logit model assumes that individuals first choose the group of sites and then a site within that group. This study assumes that individuals first choose a water body type (Lake Erie, rivers, or small lakes) and then a specific site. EPA used the estimated site-choice model coefficients to estimate the value to the consumer of being able to choose among Ohio recreation sites on a given day. This measure is referred to as the "***inclusive value***."

- *Modeling Trip Frequency.* The site choice models estimated in the previous step treat the total number of recreational trips taken each season as ***exogenous*** to the site selection. The Agency estimated the expected number of trips taken during the recreation season using a ***Negative Binomial Poisson model*** (Hausman et al., 1995; Feather et al., 1995; and Creel and Loomis, 1992), which treats trip frequency as a pre-season decision regarding total participation in a given recreation activity.

  EPA estimated the total number of trips during the recreation season as a function of the ***expected maximum utility*** (inclusive value) from recreational activity participation on a trip, and socioeconomic characteristics affecting demand for recreation trips (e.g., number of children in the household). The coefficient of the individual's expected maximum utility of taking a trip) provided a means of estimating the seasonal ***welfare effect*** of water quality improvements, because changes in water quality change the value of available recreation sites.

Estimating the site choice and total trip participation models jointly is theoretically possible, but computational requirements make an integrated ***utility-theoretic*** model infeasible. EPA estimated separate site choice and trip frequency models for the four recreational activities: boating, swimming, fishing, and near-water recreation (e.g., viewing wildlife).[1]

The Agency used estimated coefficients of the ***indirect utility function*** with estimated changes in water quality to calculate per-trip changes in consumer welfare from improved water quality at recreation sites within each consumer choice set. Trip frequency per season increases if site water quality changes are substantial. A sample consumer's expected seasonal welfare gain is therefore a function of both welfare gain per trip and the estimated change in number of trips per season.

Combining the trip frequency model's prediction of trips under the baseline and post-compliance and the site choice model's corresponding per-trip welfare measure yields the ***total seasonal welfare*** measure.

EPA calculated each individual's seasonal welfare gain for each recreation activity from post-compliance water quality changes, and then used Census population data to aggregate the estimated welfare change to the state level. The sum of estimated welfare changes over the four recreation activities yielded estimates of total welfare gain.

To analyze water quality improvement benefits in the RUM framework, EPA used available discharge, ambient concentration, and other relevant data to measure baseline and post-compliance water quality at the impact sites. Appendix H provides detail on water quality modeling used in this analysis.

21.1.2 Modeling the Site Choice Decision

EPA used the RUM framework to estimate the probability of a consumer visiting a recreation site. This framework is based on the assumption that a consumer derives utility from the recreational activity at each recreation site. Each visit decision involves choosing one site and excluding others.

The consumer's decision involves comparing each site and choosing the site that produces the maximum utility. An observer cannot measure all potential determinants of consumer utility, so the indirect utility function will have a non-random element (V) and a random error term (ξ), such that the actual determinants of consumer utility $V' = V + \xi$. The probability (π_{jn}) that site *j* will be visited by an individual *n* is defined as:

$$\pi_{jn} = Pr(V_{jn} + \xi_{jn} > V_{sn} + \xi_{sn}) \tag{21.1}$$

where:

$V_{jn} + \xi_{jn}$ = utility of visiting site *j*, and
$V_{sn} + \xi_{sn}$ = utility of visiting a substitute site.

Estimating the model requires specifying the functional form of the indirect utility function, V, in which site choice is modeled as a function of site characteristics and the "price" to visit particular sites. For example, a set of conditional utility functions (one for each site alternative *j* in the choice set) can be determined as follows:

$$V_{jn} = \beta_M(M_{jn} - P_{jn}) + \beta X_{jn} \tag{21.2}$$

where:

V_{jn} = the utility realized from a conventional budget-constrained, utility maximization model conditional on choice of site *j* by consumer *n*;
β_M = marginal utility of income;
M_{jn} = the income of individual *n* available to visit site *j*;

[1] The Agency also attempted a model structure that allows for interaction among the choice of recreational activities. In this model, a person first chooses a recreational activity and then chooses a site. This model did not perform very well because less than ten percent of recreational users included in the dataset participate in all four activities.

P_{jn} = a composite measure of travel and time costs for consumer *n* on site alternative *j*;
β = a vector of coefficients representing the marginal utility of a specified site characteristic to be estimated along with β_M (e.g., size of the water body, presence of boating ramps); and
X_{jn} = a vector of site characteristics for site alternative *j* as perceived by consumer *n*. These characteristics include the actual monitored and/or modeled water quality parameters that are hypothesized to be determinants of consumer valuation of water-based recreation resources, and that may also be affected by the MP&M regulation.

The magnitude of the coefficients in Equation 21.2 reflects the relative importance of site characteristics when consumers decide which site to visit. The coefficients (β) of water quality characteristics of recreation sites are expected to be positive; that is, all else being equal, consumers of water-based recreation would prefer "cleaner" recreation sites. The coefficient on travel cost is expected to be negative, i.e., consumers prefer lower travel costs.

To estimate the site choice probabilities, EPA specified and estimated a nested multinomial logit model (NMNL) for fishing, boating, and swimming activities. The nested structure explicitly groups similar alternatives, which allows for a richer pattern of substitution among alternative sites. The NMNL is based on the assumption that an individual chooses first between groups of alternatives and then, within the chosen group, between individual alternatives. For this analysis, EPA grouped all recreational sites in Ohio by water body type based on site similarities. EPA tested various alternative site groupings, but the models presented here were most successful at explaining the probability of selecting a site. The best model used the following activity-specific site groupings:[2]

- Fishing model:
  - Group 1: Lake Erie sites;
  - Group 2: river sites;
  - Group 3: small lakes and reservoirs;

- Boating model:
  - Group 1: Lake Erie sites;
  - Group 2: inland sites, including rivers, small lakes, and reservoirs;

- Swimming model:
  - Group 1: Lake Erie sites;
  - Group 2: inland sites, including rivers, small lakes, and reservoirs;

- Viewing model: EPA used a non-nested model in which an individual compares all sites and chooses the one offering the highest utility level for each trip occasion.

First, the Agency attempted to estimate a nested model based on the three water body types lakes, rivers, and Lake Erie for all four recreational activities included in the analysis. This structure, however, performed well only for fishing. A two-nested model that included inland and Lake Erie sites seemed to perform better for the boating and swimming models. None of the nested structures performed well for participants in near-water/wildlife viewing activities.

This finding is not surprising because sites are grouped based on their similarities within a given nest. It is reasonable to assume that inland lakes, rivers, and Lake Erie sites are dissimilar from an angler's point of view, because each of the three water body types is likely to support different fish species. Lake sites may therefore not be close substitutes for rivers sites. For other activities, differences in fishery resources across water body types are unlikely to be important. Water body size and the presence of recreational amenities are likely to play a more important role than differences in fish species and the type of aquatic habitat. Lake and river sites may therefore be regarded as substitutes for each other by boaters and swimmers. Lake Erie, on the other hand, is a unique water resource that differs from inland water bodies because of its physical characteristics (e.g., size and water temperature); river and lake sites are therefore not likely to be considered substitutes for Lake Erie sites. Finally, participants in near-water recreation use water resources indirectly and are therefore more likely to regard recreational sites located on different water body types as close substitutes to each other. For this reason, the viewing model is a simple logit model without a nested structure.

[2] Three of the four models (fishing, boating, and swimming) passed specification tests for appropriateness of a nested structure (see Section 21.3 for detail). Test results showed that only two site groups are appropriate for the boating and swimming models inland sites (rivers, small lakes, and reservoirs) and Lake Erie sites in Ohio. The fourth activity, wildlife viewing, did not pass specification tests for a nested structure and was estimated as a flat ***multinomial logit*** ***(MNL)*** model.

The models assume that an individual first decides to visit a specific water body grouping (hereafter, region), then decides which site within that group to visit. An individual probability of visiting site *j*, given the choice of region *R*, is a simple multinomial logit. If the random terms ξ_{nj} for individual *n* at site *j* are independently and identically distributed and have an extreme value Weibull distribution, then π_{jn} takes the form (McFadden, 1981):

$$\pi_{jn|r} = \frac{e^{V_{jn}}}{\sum_{j \in r} e^{V_{jn}}} \tag{21.3}$$

where:

$\pi_{jn|r}$ = probability of selecting site *j* in region *r*;

$e^{V_{jn}}$ = the consumer's utility from visiting site *j*;

r = regions -- "Lake Erie," "rivers," etc. as specified above for a given activity; and

$\sum_{j \in r} e^{V_{in}}$ = the sum of the consumer's utility at each site *j* for all sites in the opportunity set for region *r*.

Estimated parameters of the indirect utility function are then used to estimate the inclusive value. For consumer *n*, the inclusive value measures the overall quality of recreational opportunities for each water-based activity and represents the expected maximum utility of taking a trip. Note that, although EPA used a random draw from the opportunity set for the purpose of estimating the model parameters, the Agency calculated the inclusive value (i.e., the expected maximum utility) using all recreation sites in the consumer's opportunity set in a given region.

The inclusive value is calculated as the log of the denominator in Equation 21.2 (McFadden, 1981).

$$I_r = \ln\left(\sum_{j=1}^{J} e^{V_{jn}(W)}\right) \tag{21.4}$$

where:

I_r = inclusive value for sites associated with region *R*;

$e^{V_{jn}}$ = individual *n*'s utility from visiting site *j*; and

W = a vector of baseline water quality characteristics.

The probability of choosing a particular region is:

$$\pi_r = \frac{e^{I_r \gamma_r}}{\sum_{r=1}^{r=R} e^{I_r \gamma_r}} \tag{21.5}$$

where:

π_r = probability of selecting region *r*;

I_r = the inclusive values for a given region;

γ_r = the coefficient on the inclusive value for a given region; and

r = activity-specific regions (e.g., "Lake Erie," "rivers," and "small lakes" for fishing).

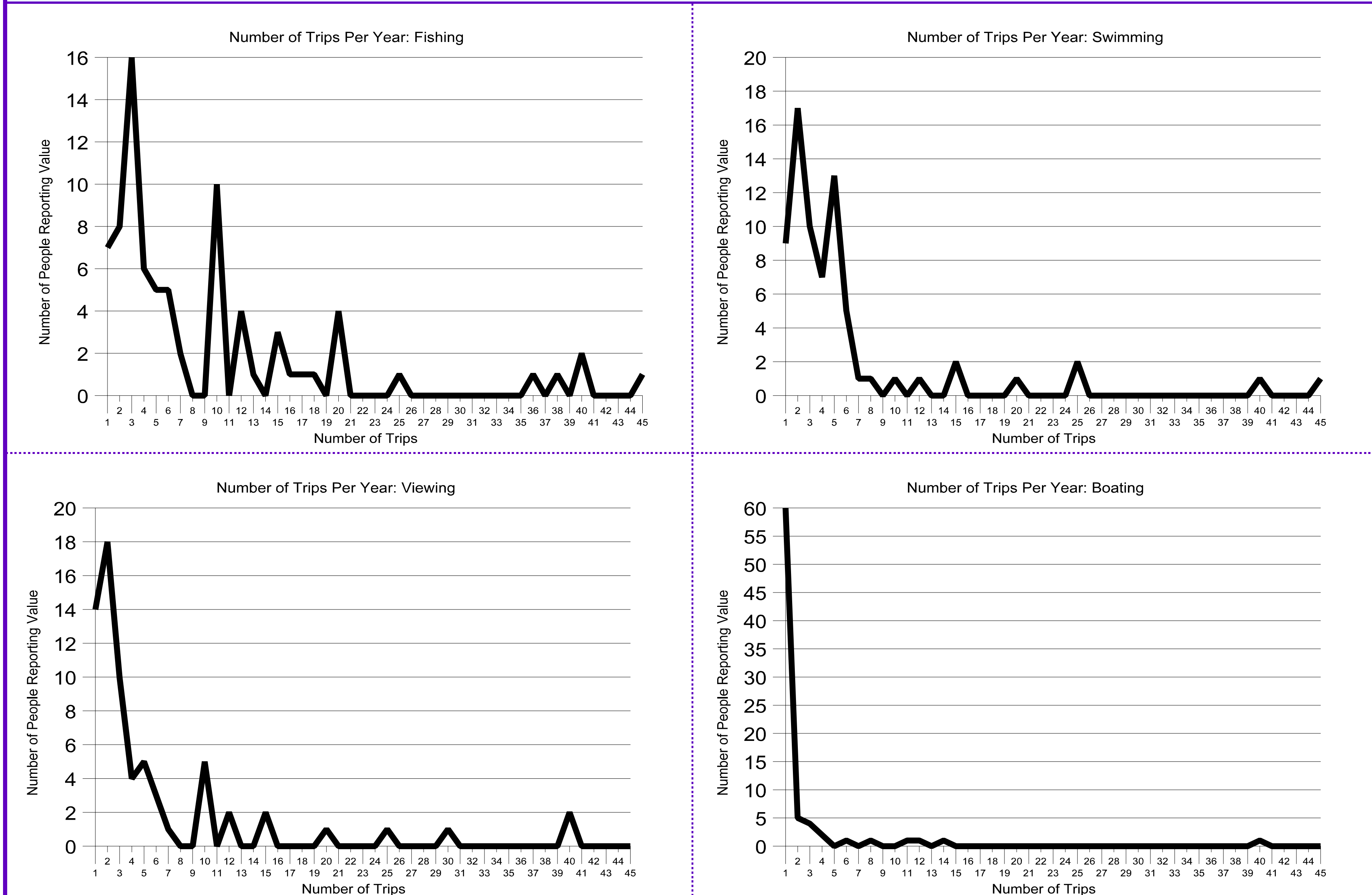
To estimate the model described by Equations 21.2 and 21.5, EPA used a standard statistical software package, ***LIMDEP***.

21.1.3 Modeling Trip Participation

After modeling the site choice decision, the next step modeled the determinants of the number of water-based recreation trips a consumer takes during a season. To link the quality of available recreation sites with consumer demand for recreation trips, EPA modeled the number of recreation trips taken during the recreation season as a function of the inclusive value estimated in the previous step and socioeconomic characteristics affecting demand for recreation activities. The dependent variable, the number of recreation trips taken by an individual during the recreation season, is an integer value greater than or equal to zero. To account for the non-negative property of the dependent variable, EPA used count data models based on probability densities that have the non-negative integers as their domain.

One of the simplest count data models is a ***Poisson estimation process***, which is commonly used with count data, such as number of recreation trips taken during the recreation season. Inherent in the model specification is the assumption that each observation of a number of trips is drawn from a ***Poisson distribution***. Such a distribution favors a large number of observations with small values (e.g., two trips, four trips) or zeros, resulting in its being skewed toward the lower end. Due to the nature of the observed number of trips, it is quite reasonable to assume that the underlying distribution can be characterized as a Poisson distribution. Figure 21.1 shows the number of recreation trips taken per year and the number of respondents who reported taking that number of trips.

Figure 21.1: Number of Trips Per Year By Activity Type



Source: U.S. EPA analysis of NDS data (U.S. EPA, 1994)

Estimating the Poisson model is similar to estimating a nonlinear regression. The single parameter of the Poisson distribution is λ, which is both the mean and variance of y_n. The probability that the actual number of trips taken is equal to the estimated number of trips is estimated as follows (Green, 1993):

$$Prob(Y_n = y_n) = \frac{e^{-\lambda_n} \lambda_n^{y_n}}{y_n!} \tag{21.6}$$

where:

Y_n = the actual number of trips taken by an individual in the sample;
y_n = the estimated number of trips taken by an individual in the sample;
n = 1, 2,..., *N*, the number of individuals in the sample; and
λ_n = $\beta' X$, expected number of trips for an individual in the sample, where X is a vector of variables affecting the demand for recreational trips (e.g., inclusive values and socioeconomic characteristics) and β is the vector of estimated coefficients.

From Equation 21.6, the expected number of water-based recreation trips per recreation activity season taken by an individual is given by:

$$E[y_n | x_n] = Var[y_n | x_n] = e^{\beta' x_n} \tag{21.7}$$

where:

$E[y_n|x_n]$ = the expected number of trips, y_n, given x_n;
$Var[y_n|x_n]$ = the variance of the number trips, y_n, given x_n;
β = a vector of coefficients on x; and
x = a matrix of socioeconomic variables and inclusive values.

An empirical drawback of the Poisson model is that the variance of the number of trips taken must be equal to the mean number of trips, and this equality is not always supported by actual data. In particular, the NDS survey data exhibit ***overdispersion***, a condition where variance exceeds the mean. The estimated variance-to-mean ratios of the number of trips in the NDS data sample are 31, 27.9, 35.6, and 10.5 for fishing, swimming, viewing, and boating trips, respectively. Overdispersion is therefore present in the data set.

To address the problem of overdispersion, EPA used the ***negative binomial regression model***, an extension of the Poisson regression model, which allows the variance of the number of trips to differ from the mean. In the negative binomial model, λ is respecified so that (Green, 1993):

$$\ln \lambda_n = \beta X_n + \epsilon \tag{21.8}$$

where the error term (ϵ) has a gamma distribution, $E[\exp(\epsilon_i)]$ is equal to 1.0, and the variance of ϵ is α.

The resulting probability distribution is:

$$Prob[Y = y_n | \epsilon] = \frac{e^{\lambda_n} \exp(\epsilon) \lambda_n^{y_n}}{y_n!} \tag{21.9}$$

where:

y_n = 0,1,2... number of trips taken by individual *n* in the sample;
n = 1,2,..., *N* number of individuals in the sample; and
λ_n = expected number of trips for an individual in the sample.

Integrating ϵ from Equation 21.9 produces the unconditional distribution of y_n. The negative binomial model has an additional parameter, α, which is the overdispersion parameter, such that:

$$Var[y_n] = E[y_n](1 + \alpha E[y_n]) \tag{21.10}$$

The overdispersion rate is then given by the following equation:

$$\frac{Var[y_n]}{E[y_n]} = 1 + \alpha E[y_n] \tag{21.11}$$

EPA used the negative binomial model to predict the seasonal number of recreation trips for each recreation activity based on the inclusive value, individual socioeconomic characteristics, and the overdispersion parameter, α. If the inclusive value has the anticipated positive sign, then increases in the inclusive value stemming from improved ambient water quality at recreation sites will lead to an increase in the number of trips. The combined MNL model site choice and count data trip participation models allowed the Agency to account for changes in per-trip welfare values, and for increased trip participation in response to improved ambient water quality at recreation sites.

21.1.4 Calculating Welfare Changes from Water Quality Improvements

EPA estimated the welfare change associated with water quality improvements from the baseline to post-compliance conditions as a ***compensating variation (CV)***, which equates the expected value of realized utility under the baseline and post-compliance conditions. The expected seasonal change in welfare attributed to the quality improvements for an individual *n* in the sample consists of two components:

- per trip welfare gain, and
- increased number of trips under the post-compliance water quality condition.

The Agency first calculated the welfare gain from water quality improvement for each consumer on a given day by using a CV measure for consumer *n* (Kling and Thompson, 1996):

$$CV_n = \frac{\ln\left[\sum_{r=1}^{R}\left(\sum_{j=1}^{J_r} e^{V_{jn}(W^0)}\right)\right] - \ln\left[\sum_{r=1}^{R}\left(\sum_{j=1}^{J_r} e^{V_{jn}(W^1)}\right)\right]}{\beta_M} \tag{21.12}$$

where:

CV_n = the compensating variation for individual *n* at site *j* on a given day;

r = "Lake Erie," "inland," etc.

j = $1,\ldots J_r$ represents a set of alternative sites for a given recreational activity in region *r*;

$\ln\left[\sum_{r=1}^{R}\left(\sum_{j=1}^{J_r} e^{V_{jn}(W)}\right)\right]$ = the inclusive value index (I);

W^0 = a vector of information describing baseline water quality;

W^1 = a vector of information describing post-compliance water quality; and

β_M = the implicit coefficient on income that influences recreation behavior.

In deriving Equation 21.12, EPA assumed that the marginal utility of income, β_M, is constant across alternatives (as well as across quality changes). If this assumption does not apply, the derivation of Eq. 21.12 is more complicated (Hausman et al., 1995).

EPA then estimated the low and high values of the seasonal welfare gain for individual n in the sample as follows: [3]

$$W_{low,\,n} = \frac{(I^1 - I^0) \times Y^0}{-\beta_\mu} \tag{21.13}$$

$$W_{high,\,n} = \frac{(I^1 - I^0) \times Y^1}{-\beta_\mu} \tag{21.14}$$

where:

$W_{low,\,n}$	=	lower bound estimate of the seasonal welfare gain for individual n;
$W_{high,\,n}$	=	upper bound estimate of the seasonal welfare gain for individual n;
I^1	=	the post-policy inclusive value;
Y^1	=	the estimated number of trips after water quality improvement;
I^0	=	the baseline inclusive value;
Y^0	=	the estimated number of trips in the baseline; and
β_Y	=	the implicit coefficient on income that influences recreation behavior.

These estimates are *per individual* in the population for those individuals meeting qualifications for inclusion in the NDS response set (i.e., respondents whose home state is Ohio and respondents from the neighboring states whose last trip was to Ohio's sites).[4] EPA extrapolated the estimates of value per individual to the Ohio state level based on Census data (U.S. Bureau of the Census, 2000). The following section details the extrapolation method used in the analysis.

21.1.5 Extrapolating Results to the State Level

EPA used a simplified extrapolation technique to estimate the state-level benefits. EPA first estimated the number of participants in fishing, swimming, boating, and wildlife viewing in Ohio, based on the estimated percentage of the NDS survey respondents residing in Ohio who participate in a given activity and the state adult population. The 2000 Census data provide information on the number of Ohio residents aged 16 and older. EPA then multiplied the estimated average seasonal welfare gain per participant in a given recreational activity by the corresponding number of recreational users. The total welfare gain to the users of water-based recreation in Ohio is the sum of fishing, swimming, boating, and wildlife viewing benefits.

21.2 Data

This section describes the data and supporting analyses required to implement the RUM analysis. The following general categories of data and supporting analyses are required:

- information on the consumers of water-based recreation responding to the NDS in Ohio;
- recreation sites identified for the water quality and RUM analyses, including the sites visited by consumers of water-based recreational activity and supplemental sites in their choice sets;
- estimated price of visiting the sites. The "visit price" is estimated as a function of travel distance (and travel time) between each consumer's hometown and each site in the choice set; and
- information on site characteristics likely to be important determinants of consumer behavior. Of particular importance to this analysis are the water quality and related characteristics of sites in the choice set, and how those characteristics may be expected to change as a result of regulation.

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[3] EPA selected this approach for calculating seasonal welfare gain per individual based on Dr. Parsons' recommendation (G.R. Parsons, 1999).

[4] Section 21.2.1 provides a detailed description of the data sample used in the analysis.

The following sections discuss each category of data and/or supporting analysis below.

21.2.1 The Ohio Data

EPA obtained information on survey respondent socioeconomic characteristics and recreation behavior, including last trip profile and the annual number of trips associated with each water-based activity, from the NDS (U.S. EPA, 1994). The 1994 survey collected data on demographic characteristics and water-based recreation behavior using a nationwide stratified random sample of 13,059 individuals aged 16 and over. Respondents reported on water-based recreation trips taken within the past 12 months, including the primary purpose of their trips (e.g., fishing, boating, swimming, and viewing), total number of trips, trip length, distance to the recreation site(s), and number of participants. Where fishing was the primary purpose of a trip, respondents were also asked to state the number of fish caught. Table 21.1 shows the number of trips taken per year by primary recreation activity, as reported in the NDS.

EPA selected case study observations for Ohio residents who took trips within or outside of the state. Trips to Ohio recreation sites by residents of neighboring states were also included in the site choice models, but not in the trip participation models.[5] All four activity models included single-day trips only. EPA included only activity participants with valid hometown ZIP codes, whose destination site was uniquely identified. The Agency used data on both Ohio participants and Ohio non-participants to estimate total seasonal trips, but included only Ohio participants and several residents of nearby states in the site choice models. Although they could not be used in the site choice model, participant observations from Ohio with missing location information were used to analyze the number of trips. Tables 21.1 and 21.2 list valid observations by activity, residence, and model type. Figure 21.2 illustrates the distribution of the sample observations in relation to the location of MP&M facilities affected by the rule in Ohio.

Table 21.1: Classification of Sample Observations for Estimation of the Site Choice Models

	Total Ohio Residents	Ohio Residents with Last Trip In-State	Valid Ohio Residents with Last Trip In-State	Valid Ohio Residents with Last Trip Outside State	Valid Nonresidents with Last Trip in Ohio	Valid for Site Choice Model
Participants (Total)	609	408	237	35	11	297
Fishing	122	103	66	9	0	84
Swimming	147	100	58	14	2	76
Viewing	231	126	64	2	7	73
Boating	109	79	49	10	2	64

Source: U.S. EPA analysis.

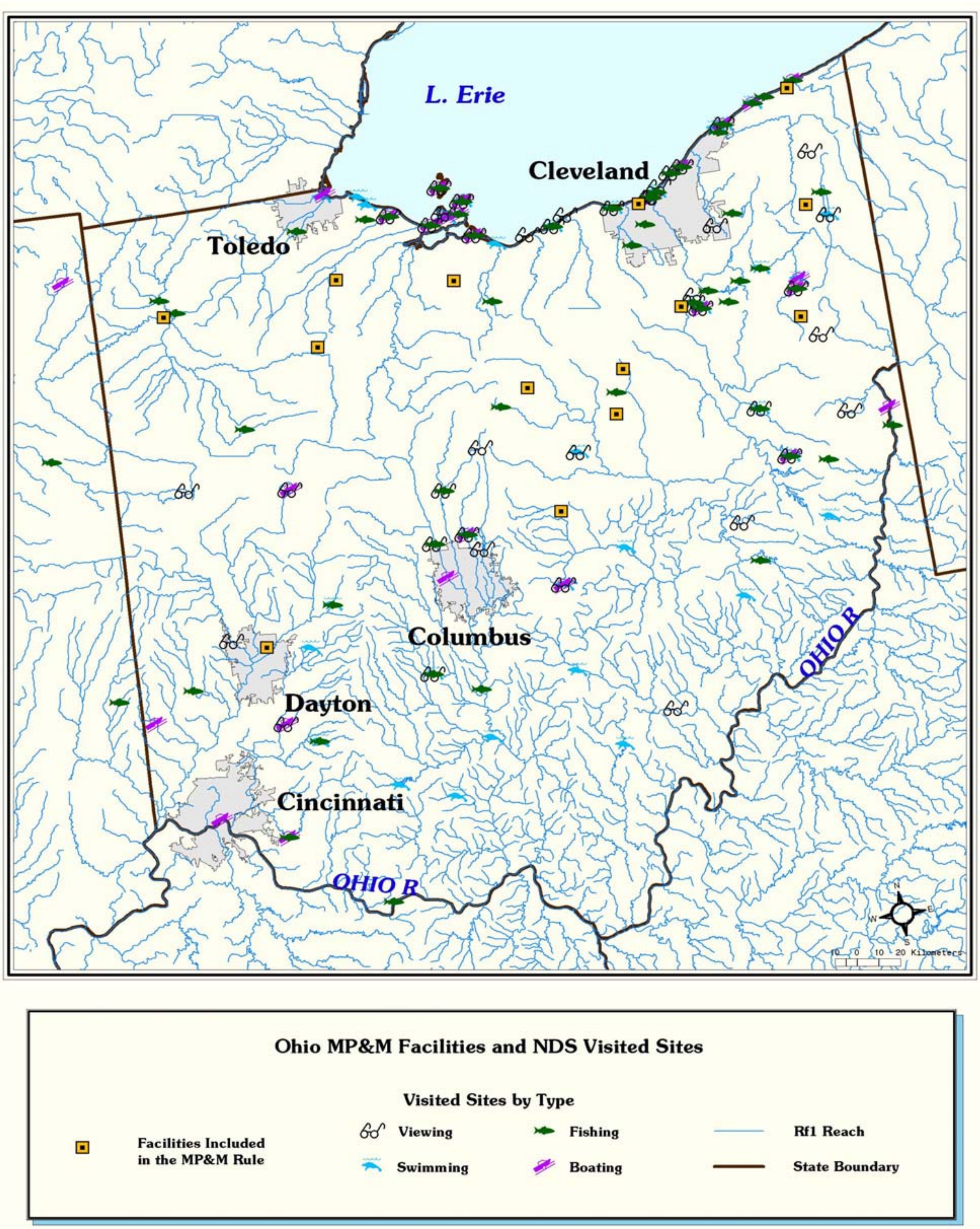
[5] These additional observations total 11 across the four activities and thus represent only a small fraction of total observations. Including only Ohio respondents in the trip participation models underestimates the benefits associated with water quality improvements, because the welfare gains to recreators from neighboring states are ignored.

Table 21.2: Classification of Sample Observations for Estimation of the Trip Participation Models

Ohio Residents	Total	Residents with Last Trip In-State	Residents with Last Trip Outside State	Valid for Trip Participation Model
Non-Participants	300			291
Participants (Total)	609	408	34	322
Fishing	122	103	4	84
Swimming	147	100	9	78
Viewing	231	126	7	75
Boating	109	79	14	85
Total Observations	909	408	34	613

Source: U.S. EPA analysis.

Figure 21.2: Location of MP&M Facilities in Relation to the Visited Sites



Source: *U.S. EPA analysis.*

21.2.2 Estimating the Price of Visits to Sites

EPA estimated trip "price" for each consumer of water-based recreation as the sum of travel costs plus the opportunity cost of time, following the procedure described in Haab et al. (2000). Based on Parsons and Kealy (1992), this study assumed that time spent "on-site" is constant across sites and can be ignored in the price calculation.

To estimate consumers' travel costs, EPA first used ZipFip software to calculate the one-way distance to each site for each participant.[6] The average estimated one-way distance to the site visited is 37.56 miles. EPA then multiplied round-trip distance by average motor vehicle cost per mile ($0.29, 1993 dollars).[7,8] The model adds the opportunity cost of travel time, measured in terms of wages lost, to the travel cost for those who would have lost income by taking the recreation trip. For these consumers the dummy variable LOSEINC equals one. Travel times equal the round-trip distance divided by a travel speed of 40 mph and multiplied by the individual's hourly wage as calculated below.

The travel cost variable in the model was calculated as follows:

$$Visit\ Price = \begin{cases} Round\ Trip\ Distance \times \$.29 + \dfrac{Round\ Trip\ Distance}{40\ mph} \times (Wage) & If\ LOSEINC = 1 \\ Round\ Trip\ Distance \times \$.29 & If\ LOSEINC = 0 \end{cases} \tag{21.15}$$

Individuals not losing income (e.g., individuals taking vacation or a weekend trip or individuals whose work schedule is not flexible) do not face lost wages as a result of the trip and inclusion of the opportunity cost of time would be inappropriate. These consumers still have an opportunity cost for their travel time, which could otherwise be spent doing something else, like fishing. In other words, a shorter distance traveled allows for a longer time spent at the recreation site. For these consumers, the analysis included an additional round-trip travel time variable calculated as:

$$Travel\ Time = \begin{cases} Round\ Trip\ Distance/40 & If\ LOSEINC = 0 \\ 0 & If\ LOSEINC = 1 \end{cases} \tag{21.16}$$

The average one-way estimated travel time to the visited site is 56.34 minutes.[9]

21.2.3 Site Characteristics

EPA identified 1,954 recreation sites on 1,631 reaches in the universal opportunity set. Of these, 580 observations are known recreational sites (e.g. parks); 1,366 observations are ***Reach File 1*** ***(RF1)*** reaches without a known recreational site; and eight observations are neither located in RF1 nor identified as known recreation sites but were visited by an NDS respondent.

[6] The program was created by Daniel Hellerstein and is available through the USDA at http://usda.maunlib.cornell.edu/datasets/general/93014.

[7] Note that all expenditures are in 1993 dollars because the NDS trip choices and the associated expenditure occurred in 1993.

[8] The estimate of motor vehicle cost per mile was based on estimates compiled by the Insurance Information Institute.

[9] The average travel time to the visited site was fairly uniform across the activities. Average one-way time to the visited site was 51.38 minutes, 71.64 minutes, 43.76 minutes, and 58.57 minutes for fishing, boating, swimming, and viewing, respectively.

Each consumer choice set theoretically includes hundreds of substitutable recreation sites in Ohio and in the neighboring states. To prevent the recreation site analysis from becoming unmanageable, EPA analyzed a sample of recreation sites for each consumer observation. The Agency then created a randomly-drawn reduced choice set for each recreational activity as follows:[10]

- *Fishing*. The reduced choice set consists of 20 Lake Erie sites, 20 river sites, and 20 small lakes/reservoirs. Thus, a total individual choice set consists of 60 alternatives (including the chosen site);

- *Boating*. The reduced choice set consists of 20 Lake Erie sites and 20 inland recreation sites (including rivers and lakes/reservoirs). A total individual choice set consists of 40 alternative sites (including the chosen site);

- *Swimming*. Similar to boating, the reduced choice set consists of 20 Lake Erie sites and 20 inland recreation sites (including rivers and lakes/reservoirs). A total individual choice set consists of 40 alternative sites (including the chosen site);

- *Wildlife Viewing*. The reduced choice set consists of 40 sites, including Lake Erie, river, and small lake/reservoir sites.

Each participant choice set, by definition, includes the site actually visited by the respondent. For each consumer, EPA drew the additional sites from a geographic area defined by a distance constraint (and the water body types listed above). The Agency used a 120-mile distance limit for inland recreation sites (Ohio rivers, small lakes, or reservoirs). All Lake Erie sites are eligible for inclusion in the choice sets for all models. EPA assumed that consumers of water-based recreation would be willing to travel farther to visit Lake Erie sites, because this water resource presents unique recreational opportunities.[11] EPA used the resulting aggregate choice set of sites for all individuals participating in a given recreation activity to model consumer decisions regarding trip allocation across recreation sites.

The Agency used two classes of characteristics to estimate site choice:

- those unaffected by the MP&M regulation, but likely to determine valuation of water-based recreational resources; and

- those affected by the regulation *and* hypothesized to be significant in explaining recreation behavior and resource valuation.

Regulation-independent site characteristics include water body type and size, location characteristics, and the presence of site amenities (e.g., boat ramps, swimming beaches, picnic areas). Regulation-dependent site characteristics include regulation-affected water quality variables.

a. Regulation-independent site characteristics

Site characteristics that are likely to be important determinants of consumer valuation of water-based recreational resources but that are independent of the MP&M regulation include general site descriptors. These descriptors include the type and size of the water body and location characteristics, and the presence of site amenities. EPA obtained data on regulation-independent site characteristics from two main sources, RF1 and the Ohio Department of Natural Resources **(ODNR)**.

RF1 provided water body type (i.e., lake, river, or reservoir) and physical dimension (i.e., length, width, and depth). The dummy variables, LAKE ERIE, RIVER, and LAKE characterize water body types. If a site is located on Lake Erie, LAKE ERIE takes the value of 1; 0 otherwise. If a site is located on river, RIVER takes the value of 1; 0 otherwise. Finally, if a site is located on a small lake or reservoir, LAKE takes the value 1; 0 otherwise. Water body size was determined by the length of the reach segment in miles for rivers and Lake Erie sites. For small lakes and reservoirs, the appropriate water body size is the water body area in acres. The site choice models use the logarithm of water body size as a measure of site importance,

[10] McFadden (1981) has shown that estimating a model using random draws can give unbiased estimates of the model with the full set of alternatives.

[11] Travel distance from respondent's hometown to the Lake Erie sites did not exceed 250 miles.

because people are more likely to be aware of large water bodies.[12] Water body size data for sites not located in RF1 came from the ODNR.

ODNR, supplemented by the *Ohio Atlas and Gazetteer*, provided data on recreational amenities and site setting (e.g., presence/absence of boat ramps, swimming beaches, or picnic areas; public accessibility; and size of land available for recreation). EPA used land available for recreation, LN(LAND), (e.g., acreage of state park, fishing, hunting, and other recreation areas) to approximate site setting and attractiveness. Dummy variables represent the presence of three recreational amenities: BEACH is a swimming beach; RAMP is a boating ramp; and PARK indicates a park.

b. Regulation-dependent site characteristics

Selecting regulation-dependent site characteristic variables that are both policy-relevant and significant in explaining recreation behavior proved challenging. MP&M facilities discharge many pollutants, most of them unlikely to have visible indicators of degraded water quality (e.g., odor, reduced turbidity, etc). EPA hypothesized that pollutant loadings can, nonetheless, reduce the likelihood of selecting a recreation site. Reduced pollutant discharges improve water quality and aquatic habitat, thereby increasing fish populations and enhancing the recreational fishing experience. In addition, in-stream nutrient concentrations are good predictors of eutrophication, which causes aesthetic losses and may thus affect the utility of a water resource for all four recreational uses.

The connection between the policy variables (i.e., the change in concentrations of MP&M pollutants) and the effects perceived by consumers (e.g., increased catch rate, increased size of fish, greater diversity of species, or improved aesthetic qualities of the water body) are not modeled directly, but are captured implicitly in the differential valuation of water resources as reflected in the RUM analyses.

EPA considered two types of pollutant effects in defining water quality variables for model inclusion:

- visible or otherwise directly perceivable effects (e.g., water turbidity); and
- unobservable toxic effects likely to impact aquatic habitat and species adversely.

The Agency accounted for directly observable effects using the ambient concentrations of nutrients (e.g., TKN) as an explanatory variable.

Rather than include the concentrations of all toxic pollutants separately, EPA constructed a variable to reflect the adverse impact potential of toxic pollutants on aquatic habitat. EPA identified recreation sites at which estimated concentrations of one or more MP&M pollutants exceeds AWQC limits for aquatic life protection, to assess the likely adverse impacts on aquatic organisms. A dummy variable, AWQC_EX, takes the value of 1 if in-stream concentrations of at least one MP&M pollutant exceed AWQC limits for aquatic life protection, 0 otherwise. This approach accounts for the fact that adverse effects on aquatic habitat are not likely to occur below a certain threshold level.

c. Biological factors

Numerous biological parameters (e.g., abundance of sport fish) that are a function of the availability and quality of suitable habitat for breeding and feeding are also likely to affect recreation behavior. To account for biological parameters affecting the demand for water-based recreation, EPA used relative ***fish abundance (Biomass)*** obtained from the ***Ohio Water Resource Inventory (OWRI)*** database (OH EPA, 1996). Relative fish abundance is measured as the total fish weight (in kg) per 300 meters. Because this variable reflects presence of both tolerant and intolerant fish species, it is less correlated with the two regulation-dependent water quality variables (i.e., TKN and AWQC) included in the analysis compared to the index of well-being ***(IWB2)*** used in the proposed rule analysis.

Chemical properties of the waters (e.g., pollutant concentrations) are likely to affect the diversity and abundance of the fishery resources. Biological parameters may also be affected by numerous anthropogenic stressors unrelated to water quality, such as over-fishing, physical alteration of habitat, invasion of exotic species, etc. Although EPA used the baseline values of relative fish abundance to estimate the site choice models, the Agency did not estimate changes in biological parameters caused by the regulation analysis due to data limitations and the challenges posed by modeling population impacts of a broad spectrum of pollutants at hundreds of recreation sites.

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[12] EPA uses the logarithm of water body size because it expects the effect of water body size on utility to diminish as that size increases.

d. Presence of fish advisories

Another important factor that may affect a recreational consumer's decision to visit a particular site is presence of ***fish consumption or contact advisories (FCAs)***. EPA obtained information on fish consumption advisories and contact advisories at reaches in Ohio from the ODNR (Ohio DNR, 1999). Fish consumption advisories and contact advisories were listed by the name of the stream or river with the consumption advisory. An advisory that applied to only part of the river included the names of cities, towns, or highways to identify the stretch of the reach for which the advisory was relevant. The name of the river and the other geographic identifiers were used to assign reach numbers from RF1 to the consumption advisories. EPA created a dummy variable for each type of advisory (i.e., fish advisories and contact advisories). The variable takes the value of 1 if the relevant advisories are present; 0 otherwise.

21.3 Site Choice Model Estimates

EPA estimated four separate models of recreational demand: fishing, boating, swimming, and viewing. The Agency classified trips by the primary activity listed by the respondent. All four activity models cover single-day trips. EPA estimated the site choice model using the site actually visited and randomly-drawn sites from the choice set for each recreation activity as described in Section 21.2-3 above.

EPA estimated activity models for five alternative choice sets (i.e., five random draws from the universal choice set), producing five sets of estimated coefficients. Mean estimates from the five alternative draws represent EPA's best estimate of actual coefficient values. Table 21.3 lists the variables used as arguments in the utility function and presents the mean estimation results for the four models. In estimating site choice models for fishing, boating, swimming, and viewing, the Agency restricted the coefficient on travel cost to be equal across all four models to ensure a constant marginal utility of income across all four activities.

The following sections provide a short description of the results of the site choice model corresponding to each recreation activity.

Table 21.3: Site Choice Model Estimation Results (Mean parameter estimates from five random draws)[a]

Variable		Activity			
		Fishing	Boating	Swimming	Viewing
TRCOST [b]		-0.044 (-22.704)	-0.044 (-22.704)	-0.044 (-22.704)	-0.044 (-22.704)
TIME [c]		-1.474 (-7.482)	-0.362 (-4.27)	-0.436 (-7.007)	-0.719 (-12.647)
RAMP [d]		0.878 (7.509)	N/A	N/A	N/A
LN(LAND) [e]		N/A	N/A	0.058 (2.431)	0.162 (7.471)
PARK [f]		N/A	N/A	0.753 (3.79)	0.787 (4.638)
BEACH [g]		N/A	N/A	0.491 (2.96)	N/A
LN(SIZE) [h]	All	N/A	0.502 (5.777)	-0.273 (-6.083)	N/A
	Lake Erie	0.908 (6.639)	N/A	N/A	0.665 (10.474)
	River	0.171(1.993)	N/A	N/A	-0.261 (-4.937)
	Lake	0.050 (-0.348)	N/A	N/A	-0.429 (-4.329)
Biomass [i]	Lake Erie	N/A	-0.130 (-1.777)	N/A	N/A
	River	0.068 (2.328)	0.017 (0.4432)	N/A	N/A
TKN [j]		-0.584 (-3.763)	-1.187 (-6.863)	-0.660 (-4.631)	-0.711 (-4.401)
AWQC [k]		-0.573 (-3.698)	-0.172 (-1.179)	N/A	N/A
Inclusive Values					
ERIE		0.811(9.895)	0.296 (6.098)	0.730 (7.466)	N/A
Inland		N/A	0.088 (2.525)	0.275 (6.302)	N/A
RIVER		0.591 (6.945)	N/A	N/A	N/A
LAKE		0.429 (2.629)	N/A	N/A	N/A
Adj. R^2		0.467	0.280	0.408	

[a] EPA performed this analysis based on five alternative draws to assess sensitivity of the estimated coefficients with respect to random draws.
[b] Travel Cost is calculated as 0.29 * round-trip distance.
[c] Travel Time is (round-trip distance / 40)*Wage.
[d] 1 if a boating ramp is present, and 0 otherwise.
[e] Log of the number of land acres.
[f] 1 if the site is a park, and 0 otherwise.
[g] 1 if a swimming beach is present, and 0 otherwise.
[h] Log of the size of the water body. For rivers and Lake Erie, this is the log of the reach segment length or Lake Erie shore segment in miles. For lakes, this is log of the lake circumference.
[i] Biomass is measured as the total fish weight (in kg) per 300 meters.
[j] In-stream concentrations of TKN (mg/l).
[k] 1 for any reach if in-stream concentrations of at least one MP&M pollutant exceeds the AWQC limits for protection of aquatic life, and 0 otherwise.
Note: T-statistic for test that the estimated coefficient equals 0 is given in parentheses beside the coefficient estimates.
N/A indicates that the variable was not included in the estimation for this activity.

Source: U.S. EPA analysis.

21.3.1 Fishing Model

The estimated fishing model includes travel cost (TRCOST), time (TIME) spent traveling, and site characteristics. The Agency included the following site characteristics in the fishing model: boat ramp (RAMP), water body size (LN(SIZE)), relative fish abundance (Biomass), TKN concentrations, and presence of AWQC exceedances. Table 21.3 shows that most coefficients have the expected sign and are significantly different from zero at the 95th percentile. Travel cost and travel time have a negative effect on the probability of selecting a site, indicating that anglers prefer to visit sites closer to their homes (other things being equal).

Anglers who fish from a boat are likely to view the presence of a boat ramp as an important factor that may affect their site choice. However, the presence of a boat ramp is unlikely to be important for anglers who fish from shore. Thus, the Agency used an interaction variable (RAMP x USE_BOAT) such that the ramp variable was turned on only if the angler reported using a boat on his last fishing trip. A positive sign on the boat ramp indicates that anglers owning a boat are more likely to choose sites with a boat ramp.

The water body size has a different effect on the probability of selecting a site in the Lake Erie, river, and small lake/reservoir groups. The larger the river or the Lake Erie shore segment, the more likely that anglers visited the reach. The size of inland lakes and reservoirs does not have a significant effect on the probability of visiting the site.

The Agency used the square root of the fish weight per 300 meters as a measure of fish abundance (Biomass). The probability of a river site visit increases as the relative fish abundance at the site increases. However, inclusion of this variable in the Lake Erie nest was not significant, which indicates that relative fish abundance does not have a significant effect on choosing a Lake Erie site. This finding is counterintuitive and is likely to be due to the lack of variation in the relative fish abundance variable for the Lake Erie sites. This variable was excluded from the Lake Erie nest in the final model presented here. Data on relative fish abundance were not available for lakes.

Finally, higher ambient concentrations of TKN, which indicate potential eutrophication problems, and presence of AWQC exceedances negatively affect the probability of site selection. In other words, anglers prefer cleaner sites, all else being equal.

Estimated inclusive values on Lake Erie sites, rivers, and small lakes lie within a unit interval [0,1] and are significantly different from 0, indicating that the nested choice structure is appropriate.[13]

EPA found other variables, tested as explanatory variables, to be insignificant, including the presence of FCAs. It might be expected, *a priori*, that the presence of an FCA decreases a site's likelihood as a fishing choice. In fact, the existence of FCAs did not significantly affect a site's probability of being chosen; 59 percent of the sites actually chosen by NDS respondents had an FCA in place. Creel surveys provided by ODNR indicated that, on average, anglers released 70 percent of their catch (ODNR, 1997). This finding suggests that recreational anglers are aware of FCAs, and catch but do not consume fish in the affected areas.

21.3.2 Boating Model

The estimated boating model includes travel cost (TRCOST), time (TIME) spent traveling, and site characteristics. The Agency included the following site characteristics in the boating model: water body size (LN(SIZE)), relative fish abundance (Biomass), TKN concentrations, and presence of AWQC exceedances. Table 21.3 shows that most coefficients have the expected sign and are significantly different from zero at the 95th percentile.

Travel cost and travel time have a negative effect on the probability of selecting a site, indicating that boaters prefer to visit sites closer to their homes (other things being equal). However, the magnitude of the travel time coefficient indicates that boaters are willing to travel farther than participants in other recreational activities. This is not surprising, since motor-boating and sailing are restricted to the sites where these activities are allowed. The positive coefficient on the water body size variable (LN(SIZE)) indicates that the larger the water body the more likely the boaters visited it.

The coefficients on water quality variables (TKN and AWQC) are negative, indicating that boaters prefer to visit cleaner sites. The Biomass coefficient is positive, but insignificant for inland sites, and negative for Lake Erie sites. The negative coefficient on this variable is likely to be due to the fact that 88 percent of the sample trips used in this model were motorboating trips. Motorboating itself is likely to be a significant environmental stressor for biological communities due to noise and turbidity associated with this activity. Thus, lower fish abundance at popular boating sites may indicate that intensive motorboating may adversely affect species abundance. As was the case with the fishing model, the estimated

[13] Inclusive values equal to 1 cause the model to collapse to a flat multinomial logit.

inclusive value is significantly different from zero and lies within a unit interval [0.1], supporting the nested model framework.

21.3.3 Swimming Model

EPA included the travel cost and time variables (TRCOST, TIME), physical characteristics of the site, and ambient TKN concentrations in the swimming model. This model also includes the presence of recreational amenities that are likely to be important to swimmers: presence of a beach, the designation of the site as a park, and the natural log of the land acres. All estimated coefficients have the expected sign and are significantly different from zero at the 95th percentile.

Price, travel time, the presence of a park with a beach, and the size of the land area around the site all increase the probability of a particular site being chosen for swimming. Swimmers are less likely to visit large sites (referring to the size of the water body) or sites with visible water quality effects as indicated by higher in-stream concentrations of TKN. As for the fishing and boating models, the estimated inclusive value is significantly different from zero and lies within a unit interval [0,1] supporting the nested model framework.

Again, some variables expected to be significant, such the presence of contact advisories, are not. This variable's insignificance probably stems from its scarcity. Of 1,954 sites included in the universal opportunity set, contact advisories are in place for only 13. (None of the sites actually visited had contact advisories in place.) The probability that a chosen site has contact advisories in place is very small, because individual choice sets are randomly selected.

The fish Biomass variable representing biological characteristics of a water body also did not have a significant influence on consumer decisions to visit a particular site and was dropped from the model. This outcome is not surprising, since abundant aquatic life may, in fact, interfere with swimming activities.

21.3.4 Viewing (Near-water Activity) Model

EPA included the travel cost and time variables (TRCOST, TIME), physical site characteristics, and ambient TKN concentrations in the viewing model. In addition, the Agency included the natural log of the land acres and the designation of the site as a park. All estimated coefficients have the expected sign and are significantly different from zero at the 95th percentile.

The probability of choosing a site for near-water activities is most significantly related to visit price, travel time, land size, and in-stream concentrations of TKN. Similarly to the fishing model, the water body size has a different effect on the probability of selecting a site in the Lake Erie, river, and small lake/reservoir groups. The larger the Lake Erie shore segment, the more likely that viewers visited the site. The negative coefficients on river and inland lake size indicate that consumers prefer smaller inland water bodies for near-water and wildlife viewing activities.

21.4 Trip Participation Model

EPA estimated the determinants of individual choice concerning how many trips to take during a recreation season with a separate model for each of the four activities. These participation models rely on socioeconomic data, and on estimates of individual utility (the inclusive value) derived from the site choice models. Variables of importance include age, ethnicity, gender, education, and the presence of young or older children in the household. Whether or not the individual owns a boat is particularly important in boating participation, and is included in the model for that activity only. Variable definitions for the trip participation model are:

- IVBASE: inclusive value, estimated using the coefficients obtained from the site choice models;
- #TRIPS: number of trips taken by the individual;
- AGE: individual's age. If the individual did not report age, their age is set to the sample mean;
- MALE: equals 1 if the individual is a male, 0 otherwise;
- NOHS: equals 1 if the individual did not complete high school, 0 otherwise;

- COLLEGE: equals 1 if the individual completed college, 0 otherwise;
- AFAM: equals 1 if the individual is African American, 0 otherwise;
- YNGKIDS: equals 1 if there are kids 6 years or younger, 0 otherwise;
- OLDKIDS: equals 1 if there are kids 7 years or older, 0 otherwise;
- OWNBT: equals 1 if individual owns a boat, 0 otherwise;
- Constant: a constant term representing each individual's utility associated with not taking a trip; and
- α (alpha): overdispersion parameter estimated by the Negative Binomial Model.

Table 21.4 presents explanatory variables and a mean value for each.

Table 21.4: Mean Values for Explanatory Variables Used in the Participation Models

Variables (Mean)	Non-Participant (N=291)	Boating (N=85)	Fishing (N=84)	Swimming (N=78)	Viewing (N=75)
# TRIPS	0.00	7.71	10.07	9.46	9.59
AGE	43.99	39.06	38.53	34.76	36.91
MALE	0.33	0.49	0.65	0.47	0.47
NOHS	0.17	0.09	0.14	0.13	0.13
COLLEGE	0.15	0.32	0.20	0.32	0.35
AFAM	0.11	0.02	0.05	0.03	0.12
YNGKIDS	0.18	0.26	0.24	0.24	0.27
OLDKIDS	0.38	0.48	0.58	0.56	0.48
OWNBT	N/A	0.53	N/A	N/A	N/A

Source: U.S. EPA analysis.

Table 21.5 presents the results for the participation models of the four recreation activities.

Table 21.5: Trip Participation Negative Binomial Model Estimates

Variables/ Statistics	Boating	Fishing	Swimming	Viewing
IVBASE	0.12 (0.71)	0.82 (2.86)	0.72 (4.57)	0.47 (3.66)
AGE	-0.07 (-4.73)	-0.04 (-2.06)	-0.06 (-2.24)	-0.05 (-2.77)
MALE	1.23 (2.75)	2.22 (3.25)	1.15 (1.52)	0.91 (2.00)
NOHS	1.29 (2.37)	-1.09 (-1.56)	-0.92 (-0.96)	0.1 (0.17)
COLLEGE	-0.19 (-0.29)	-0.40 (-0.721)	0.53 (0.71)	1.22 (2.05)
AFAM	-3.74 (-1.81)	-1.44 (-1.53)	-4.07 (-2.68)	-1.16 (-1.34)
YNGKIDS	1.51 (2.96)	-0.95 (-1.26)	0.35 (0.42)	-0.17 (-0.38)
OLDKIDS	-1.67 (-3.58)	1.11 (2.78)	0.4 (0.65)	0.8 (1.81)
OWNBT	3.82 (5.26)	N/A	N/A	N/A
Constant	0.20 (0.11)	-5.74 (-3.01)	-0.1 (-0.06)	-1.98 (-1.6)
Alpha α	5.77 (5.85)	9.03 (7.16)	8.92 (6.78)	8.17 (6.03)

Note: T-statistic for test that coefficient equals 0 is given in parentheses below the coefficient estimates.
N/A indicates that the variable was not included in the estimation for this activity.

Source: U.S. EPA analysis.

Parameter estimates of the inclusive value index (IVBASE) in the swimming, fishing, and viewing models are positive and differ significantly from zero at the 95th percentile, indicating that water quality improvements have a positive effect on the number of trips taken during a recreation season.

The estimated coefficient on IVBASE in the boating model, while positive, was not statistically significant. Taking a boating trip often requires more preparation (e.g., taking a boat to the water body) than taking other trips. Therefore, although water quality improvements increase the value of a boating day, factors other than water quality are likely to have a stronger impact on the number of boating trips per season.

The AGE variable is negative and significant for all four recreation activities: younger people are likely to take more recreation trips. Ethnicity and gender (the AFAM and MALE variables) also have a significant impact on whether an individual participates in water-based recreation. African Americans living in Ohio are less likely to participate in any of the four recreation activities than representatives of other ethnic groups. Males are more likely than females to participate in any of the recreation activities.

Education also influences trip frequency significantly. People who did not complete high school (NOHS=1) tend to take fewer fishing or swimming trips. Those with a college degree (COLLEGE=1) are more likely to participate in swimming and viewing. Respondents who attended college are less likely, however, to participate in fishing and boating than those who completed only a high school education. For the boating model, the COLLEGE variable is not significantly different from zero.

The presence of older children (OLDKIDS) in the household is associated with greater participation in swimming, viewing (near-water recreation), and fishing activities, but is not a significant determinant in decisions to participate in boating. Younger children in the household (YNGKIDS) tends to lead to greater participation in boating and swimming, but leads to fewer fishing or viewing trips.

21.5 Estimating Benefits from Reduced MP&M Discharges in Ohio

21.5.1 Benefiting Reaches in Ohio

EPA identified reaches where it expects the MP&M rule to eliminate or reduce the number of existing AWQC exceedances (hereafter, benefiting reaches). The Agency first identified the reaches in which baseline discharges from industrial sources, including both MP&M and non-MP&M facilities, caused one or more pollutant concentrations to exceed AWQC limits for aquatic species. A reach is considered to benefit from the MP&M rule if at least one AWQC exceedance is eliminated due to reduced MP&M discharges. Although the method for identifying benefiting reaches is similar to the method used in the national analysis (see Chapter 15 for detail), there are three notable differences:

- Unlike the national analysis, the Ohio case study incorporates information on all industrial and municipal point source discharges and non-point sources to assess in-stream concentrations of toxic and nonconventional pollutants in the baseline and post-compliance. Appendix H provides information on the data sources and methods used to assess ambient water quality conditions in Ohio.

- The water quality model used in this analysis estimates ambient pollutant concentrations in the reaches receiving discharges from MP&M facilities and reaches below the initial discharge reach. Appendix H provides detail on the water quality model used in this analysis.

- The analysis of recreational benefits accounts for changes in TKN concentrations.

EPA's analysis indicates that pollutant concentrations at the baseline discharge levels from all industrial sources (including all MP&M facilities) exceed acute exposure criteria for aquatic life on 15 reaches, and exceed chronic exposure criteria for protection of aquatic species on 21 reaches. EPA estimates that reducing pollutant discharges from oily waste facilities directly discharging to the receiving streams would not eliminate all concentrations in excess of the acute aquatic life exposure criteria or the chronic exposure criteria on any reach under the final rule; it would reduce the number of acute and chronic exceedances on one reach.

In addition, baseline pollutant concentrations exceed human health-based AWQC for consumption of water and organisms on three reaches and exceed AQWC for consumption of organisms only on two reaches. EPA estimates that reducing pollutant discharges from oily waste facilities directly discharging to the receiving streams would reduce the number of pollutants exceeding the human health-based AWQC on one reach under the final rule; it would not eliminate all human health-based AQWC exceedances on any reach in Ohio. Table 21.6 summarizes these results. In addition, the final regulation is estimated to reduce in-stream concentrations of TKN in the affected reaches. The estimated average reductions are 0.54 percent in lakes and 0.45 percent in rivers and streams.

Table 21.6.: Estimated MP&M Discharge Reaches with MP&M Pollutant Concentrations in Excess of AWQC Limits for the Oily Wastes Subcategory for Protection of Aquatic Species or Human Health

Regulatory Status	Number of Reaches with Concentrations Exceeding AWQC Limits for Human Health		Number of Reaches with Concentrations Exceeding AWQC Limits for Aquatic Species		Number of Benefiting Reaches	
	H20 and Organisms	Org. Only	Acute	Chronic	All AWQC Exceedances Eliminated	Reaches with Some AWQC Exceedances Eliminated
Baseline	3	2	15	21	-	-
Final Regulation	3	2	15	21	0	1

Source: U.S. EPA analysis.

21.5.2 Estimating Recreational Benefits in Ohio

To estimate peoples' willingness-to-pay for water quality improvements, the Agency first calculated per-person seasonal welfare gain corresponding to the final regulation. Table 21.7 presents, for each recreation activity, the compensating variation per trip (the median value over all individuals in the sample) associated with the reduced MP&M discharges. Because the trip choices and the associated expenditures occurred in 1993, the welfare gain was calculated in 1993 dollars and then adjusted to 2001 dollars based on the Consumer Price Index (CPI).

The model indicates that the reductions in MP&M discharges from the final regulation result in a modest increase in per-trip values for three of the four recreation activities (fishing, viewing, and swimming). There is no welfare gain to boaters from improved water quality under the post-compliance scenario.[14] Table 21.7 provides the mean estimates of welfare gain per recreational user in Ohio.

Table 21.7: Welfare Gain per Recreational User in Ohio (2001$)

	Per Trip Welfare Gain	Average Number of Trips per Person per Year	Mean Seasonal Welfare Gain
Fishing	$0.02	13.6	$0.17
Boating	$0.00	6.22	$0.00
Viewing	$0.01	9.26	$0.11
Swimming	$0.01	8.72	$0.01

Source: U.S. EPA analysis.

Table 21.7 also reports seasonal compensating variation per individual. The reported seasonal welfare gain includes both the increase in the utility from better water quality at the available recreation sites receiving MP&M discharges and the increase in utility from greater recreational trip participation.

As noted above, the Ohio case study evaluated changes in the water resource values from both reduced discharges of TKN and reduced frequency of AWQC exceedances. Changes in TKN concentration in the Ohio water bodies resulting from reduced MP&M discharges from the Oily Wastes subcategory account for approximately 96 percent of the monetary value of benefits resulting from the final rule.

[14] The choice set of recreational sites available to boaters was restricted to the sites where motorboating and sailing is permitted because the majority of Ohio boaters included in this analysis used either motor or sail boats. Water quality improvements at the sites where boating is not allowed does not result in welfare gain to boaters.

Both the per-trip and seasonal welfare estimates are much lower than values reported in the existing studies of water-based recreation. This is not surprising, since the water quality changes expected from the final rule are very modest.

To calculate state-level recreational benefits from the final rule, EPA first calculated seasonal welfare gain from water quality improvements per individual in the sample. The Agency then multiplied the average welfare gain per individual by the corresponding number of participants in a given activity (see Section 21.1.5 above for detail). The resulting product is the annual benefit from the final MP&M rule to consumers of a given water-based recreation activity in Ohio. Table 21.8 summarizes state-level results.

Table 21.8: Estimated Recreational and Nonuse Benefits from Reduced MP&M Discharges from the Oily Wastes Subcategory in Ohio

Activity	Percentage of Ohio Residents Participating in Single-Day Trips (from NDS)	Number of Participants Aged 16 and older[a]	Total Annual Welfare Gain to Recreational Users in Ohio
Fishing	10.2%	892,283	$153,102
Boating	7.7%	676,026	$0
Viewing	9.1%	798,220	$88,047
Swimming	9.1%	798,220	$9,783
Total Recreational Use Benefit			$250,933
Nonuse Benefits			$125,466
Total Recreational Benefits (Use + Nonuse)			$375,859

[a] EPA estimated the number of participants in each recreation activity by multiplying the percent of NDS survey respondents from Ohio participating in a single day trip for each activity by the total adult population aged 16 an older (8,790,969). This analysis uses the 2000 Census data to estimate current population in Ohio.

Source: U.S. EPA analysis.

Under the final regulation, the extrapolation from the sample to the adult population in Ohio yields mean annual benefits estimates of $153,102, $9,783, $88,047, and $0 (2001$) for fishing, swimming, viewing, and boating, respectively. The total mean recreational use benefit is $250,932 (2001$). The Agency used the same approach as in the national analysis to estimate nonuse benefits (see Section 15.2.3, *Nonuse Benefits*, for detail). EPA estimated nonuse benefits as one-half of recreational use benefits for low, mid, and high estimates, respectively. The estimated mean nonuse benefit is $125,466 (2001$).

21.6 Limitations and Uncertainty

21.6.1 One-State Approach

Some benefits are likely to be missed by a state-level case study. For example, residents from neighboring states undoubtedly recreate in Ohio waters, and residents of Ohio undoubtedly recreate in neighboring states. A state-by-state approach that restricts its analysis to recreation activities within the state misses these categories of benefits.[15] This omission is likely to be more significant for unique locations of high quality (e.g., Lake Erie), where participants travel significant distances, and for sites very close to state boundaries.

[15] Note that EPA used a few observation on visitors from neighboring states to estimate site choice models. The analysis does not include these observations in calculating state-level benefits from water quality improvements.

21.6.2 Including One-Day Trips Only

Use of day-trips only tends to understate recreational benefits for swimming, fishing, boating, and viewing, since recreation as part of multi-day trips is excluded. Inclusion of multi-day trips, however, can be problematic. Multi-day trips are frequently multi-activity trips. An individual might travel a substantial distance, participate in several recreation activities and go shopping and sightseeing, all as part of one trip. Recreational benefits from improved recreational opportunities for the primary activity are overstated if all travel costs are treated as though they are associated with the one recreational activity of interest. The total benefits per trip from water quality improvements are not overstated, however, if individuals participated only in several water-based activities.

21.6.3 Nonuse Benefits

Estimating nonuse benefits using the 50 percent rule is less precise than using a more sophisticated benefits transfer approach. However, limiting the benefits of water quality improvements only to recreational benefits would significantly underestimate the benefits of the rule. The effects of using the simpler approach, e.g. either overestimation or underestimation of benefits, is unknown. Other benefits include aesthetic benefits for residents living near water bodies, habitat values for a variety of species (in addition to recreational fish), and nonuse values. To correct for this limitation of using only a travel cost model, EPA quantified nonuse values in proportion to recreation values. This approach provides only a rough approximation of the value of water resources to nonusers. For example, some natural resources have high use values but small or negligible nonuse values (e.g., cows), while other species have very high nonuse values but small or negligible use values (e.g., blue whales).

21.6.4 Potential Sources of Survey Bias

The survey results could suffer from bias, such as recall bias (e.g., Westat, 1989), nonresponse bias, and sampling effects.

a. Recall bias

Recall bias can occur when respondents are asked the number of days in which they recreated over the previous season, such as in the NDS survey. Some researchers believe that recall bias tends to lead to an overstatement of the number of recreation days, particularly for more avid participants. Avid participants tend to overstate the number of recreation days, since they count days in a "typical" week and then multiply them by the number of weeks in the recreation season.[16] They often neglect to consider days missed due to bad weather, illness, travel, or when fulfilling "atypical" obligations. Some studies also found that the more salient the activity, the more "optimistic" the respondent tends to be in estimating number of recreation days. Individuals also have a tendency to overstate the number of days they participate in activities that they enjoy and value. Taken together, these sources of recall bias may result in an overstatement of the actual number of recreation days.

b. Nonresponse bias

A problem with sampling bias may arise when extrapolating sample means to population means. This could happen, for example, when avid recreation participants are more likely to respond to a survey than those who are not interested in the forms of recreation, are unable to participate, assume that the survey is not meant for them, or consider the survey not worth their time.

c. Sampling effects

Recreational demand studies frequently face two types of observations that do not fit general recreation patterns: non-participants and avid participants:

Non-participants are those individuals who would not participate in the recreation activity under any conditions. This analysis assumes that an individual is a non-participant in a particular activity if he or she did not participate in that activity at *any* site. This assumption tends to understate benefits, since some individuals may not have participated during the sampling period simply by chance, or because price/quality conditions were unfavorable during the sampling period.
Avid participants can also be problematic because they claim to participate in an activity an inordinate number of times. This

[16] Westat (1989) uses ten or more activity-days per year as an indicator of an "avid" user.

reported level of activity is sometimes correct, but often overstated, perhaps due to recall bias (see Westat, 1989). Even where the reports are correct, these observations tend to be overly influential. EPA dropped observations of participants who reported more than 100 trips per year when estimating trip participation models, to correct for potential bias caused by these observations.

GLOSSARY

ambient water quality criteria (AWQC): levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes. (http://www.epa.gov/OCEPAterms/aterms.html)

compensating variation (CV): the amount of money a person would need to pay or receive in order to leave that person as well off as they were before a change.

consumer choice set: the set of alternatives (e.g., alternative recreation sites) from which a consumer may choose.

exogenous: external to the inner workings of a system or model; variables are exogenous to the extent that they are "given" and not the result of the operation of the system or anything going on in the model itself.

expected maximum utility: see "inclusive value."

fish biomass (Biomass): measure of biological factors in the water body represented by the total fish weight in kilograms per 300 meters.

fish consumption advisories (FCAs): an official notification to the public about specific areas where fish tissue samples have been found to be contaminated by toxic chemicals which exceed FDA action limits or other accepted guidelines. Advisories may be species specific or community wide.

inclusive value: the value to the consumer of being able to choose among X alternatives (e.g., among a number of recreational sites) on a given trip occasion.

indirect utility function: gives the maximum value of utility for any given prices and money income. The indirect utility function is obtained when the quantity of goods that maximizes consumer utility subject to a budget constraint are substituted into a utility function.

inferential analyses: based on interpretation.

multinomial logit (MNL): a utility maximization model. In this model, an individual is assumed to have preferences defined over a set of alternatives (e.g., recreation sites). The choice model takes the form of comparing utilities from different alternatives and choosing the one that produces the maximum utility. In this framework, observed data consist of attributes of the choices (e.g., available recreational amenities at different sites) and the choice actually made. Usually no characteristics of the individuals are observed beyond their actual choice.

National Demand Survey for Water-Based Recreation (NDS): a U.S. EPA survey of recreational behavior. The 1994 survey collected data on socioeconomic characteristics and water-based recreation behavior using a nationwide stratified random sample of 13,059 individuals aged 16 and over. (http://www.epa.gov/opei)

negative binomial regression model: an extension of the Poisson regression model that allows the variance of the process to differ from the mean (see also Poisson distribution and Poisson estimation process).

Negative Binomial Poisson model: (see negative binomial regression model).

nested multinomial logit model (NMNL): an extension of MNL (see above). In this model, an individual is assumed to choose among different groups of alternatives first (i.e., Great Lakes or inland recreation sites) and then to choose specific alternatives (e.g., a particular river reach, lake, or Great Lakes site) in the choice set for each group.

nonconventional pollutants: a catch-all category that includes all pollutants that are not classified as priority pollutants or conventional pollutants.

Ohio Water Resource Inventory (OWRI): a biennial report to U.S. EPA and Congress required by Section 305(b) of the Clean Water Act. The report is composed of four major sections: (1) inland rivers and streams, wetlands, Lake Erie, and water program description; (2) fish tissue contaminants; (3) inland lakes, ponds, and reservoirs; and (4) groundwater.

overdispersion: condition for a distribution where the variance exceeds the mean. It usually signifies a nonrandom dispersion, for example the case where a small minority of the population is responsible for the majority of recreational trips taken.

Poisson distribution: a random variable X is defined to have a Poisson distribution if the probability density of X is given by $f_x(X)= f_x(X;\lambda) = e^{-\lambda}\lambda^x / x!$ for x = 0,1,2.., and 0 otherwise. In this model, λ is both the mean and variance of X.

Poisson estimation process: used to model discrete random variables. Typically, a Poisson random variable is a count of the number of events that occur in a certain time interval or spatial area, for example, the number of recreational trips taken during a recreational season.

priority pollutants: 126 individual chemicals that EPA routinely analyzes when assessing contaminated surface water, sediment, groundwater, or soil samples.

random utility model (RUM): a model of consumer behavior. The model contains observable determinants of consumer behavior and a random element.

Reach File 1 (RF1): a database of approximately 700,000 miles of streams and open waters in the conterminous United States. The database contains information on stream flow, time travel velocity, reach length, width, depth, and other stream attributes.

site choice model: used to determine which recreational site is chosen by the consumer. EPA estimated the likelihood that the consumer will choose a particular site as a function of site characteristics, the price paid per site visit, and household income.

Total Kjeldahl Nitrogen (TKN): the total of organic and ammonia nitrogen. TKN is determined in the same manner as organic nitrogen, except that the ammonia is not driven off before the digestion step.

travel cost model (TCM): method to determine the value of an event by evaluating expenditures by participants. Travel costs are used as a proxy for price in deriving demand curves for recreation sites. (http://www.damagevaluation.com/glossary.htm)

total seasonal welfare: see "welfare effect."

trip participation model: used to estimate the number of water-based recreational trips taken during the recreation season. EPA estimated the total number of trips during the recreation season as a function of the expected maximum utility (inclusive value) from recreational activity participation on a trip and socioeconomic characteristics affecting demand for recreation trips (e.g., number of children in the household).

utility-theoretic: consistent with the behavioral postulate that individuals act to maximize their welfare (utility) that underlines the structure of models of consumer behavior.

welfare effect: gain or loss of welfare to the group of individuals (e.g., fishermen) as a whole.

ACRONYMS

AWQC: ambient water quality criteria
CV: compensating variation
FCAs: fish consumption advisories
IWB2: index of well-being
LIMDEP: Limited Dependent Variable
MNL: multinomial logit
NDS: National Demand Survey for Water-Based Recreation
NMNL: nested multinomial logit model
ODNR: Ohio Department of Natural Resources
OWRI: Ohio Water Resource Inventory
RUM: random utility model
RF1: Reach File 1
TKN: Total Kjeldahl Nitrogen
TCM: travel cost model

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Chapter 22: MP&M Benefit-Cost Analysis in Ohio

INTRODUCTION

This chapter presents estimated benefits and costs of the final MP&M regulation in Ohio. The preceding chapter summarized the methodology and results of the case study of the expected recreational benefits from water quality improvements in Ohio. This chapter first presents estimates of the remaining three benefit categories, including:

- reduced human health risk from exposure to carcinogens and systemic health toxicants,
- changes in health risk from exposure to lead for adults and children, and
- ***publicly-owned treatment works (POTW)*** benefits.[1]

CHAPTER CONTENTS

The chapter then presents the social costs of the final regulation for the state of Ohio and compares the aggregate benefits and social costs estimates. From this analysis, EPA estimates that the final regulation will have net monetizable benefits in Ohio of $868 thousand annually (2001$).

EPA estimated MP&M costs and benefits in Ohio using methodologies similar to those used for the national-level analysis but with greater detail and coverage of information. In addition to the RUM study of recreational benefits discussed in the previous chapter, other analytical improvements included the following:

- the use of more detailed data on MP&M facilities. EPA oversampled the state of Ohio with 1,600 screeners to obtain information on co-occurrence of MP&M discharges;
- the use of data on non-MP&M discharges to estimate current baseline conditions in the state; and
- the use of a first-order decay model to estimate in-stream concentrations in the Ohio water bodies. This model allows the assessment of the environmental effects of MP&M discharges on the reaches receiving MP&M discharges and downstream reaches.

Appendix H describes the water quality model used in this analysis and the approach and data sources used to estimate total pollutant loadings from all industrial and municipal sources to Ohio's water bodies. The Agency believes that the added level of detail results in more robust benefit-cost estimates.

22.1 BENEFITS OF THE FINAL REGULATION

EPA estimates that MP&M facilities in all subcategories in Ohio discharge approximately 127.6 million pounds of pollutants per year to POTWs, and approximately 83.6 million pounds of pollutants directly to surface water. EPA estimates that the final regulation will reduce direct discharges by approximately 0.5 million pounds of pollutants annually.

[1] The final rule regulates only direct dischargers. Therefore, the selected option does not affect POTW operations.

22.1.1 Human Health Benefits (Other than Lead)

EPA estimates total monetized human health benefits from the final regulation of $14,504 (2001$). Chapter 13 details the methodologies used to estimate human health benefits from reduced exposure to carcinogens and systemic health toxicants other than lead.

a. Reduced incidence of cancer cases from consumption of contaminated fish and drinking water

Table 22.1 shows the number of cancer cases avoided by the final regulation for both the drinking water and fish consumption pathways. EPA estimates that improved water quality resulting from the final regulation will reduce the incidence of cancer cases via the drinking water and fish consumption pathways from 0.11 cases in the baseline to 0.10 cases under the final regulation, with a total annual value of $14,504. Essentially all of the cancer avoidance occurs via the fish consumption pathway, which yields annual cancer avoidance benefits of $14,503. Monetized cancer avoidance benefits from reduced drinking water contamination are negligible.

Table 22.1: Estimated Annual Benefits from Avoided Cancer Cases from Fish and Drinking Water Consumption

	Cancer Cases	Benefits (2001$)
	Baseline[a]	
Drinking Water	0.1026421	
Fish Consumption	0.00331	
Total	**0.11**	
	Final Regulation	
Drinking Water	0.1026420	negligible[b]
Fish Consumption	0.00108	$14,503
Total	**0.10**	**$14,504**

[a] The baseline includes baseline loadings from dischargers in all subcategories.
[b] Monetized cancer avoidance benefits from reduced drinking water contamination are approximately $1.

Source: U.S. EPA analysis.

b. Systemic health effects

EPA's analysis of in-waterway pollutant concentrations indicates that baseline hazard ratios, for both the fish consumption and drinking water pathways, for the population associated with sample facilities only, are less than one on all reaches but one. For those reaches with a baseline hazard ratio of less than one, EPA's analysis finds shifts in populations from higher (but less than 1.0) to lower hazard ratio value between the baseline and post-compliance cases. For the single reach with a baseline hazard ratio greater than one, the hazard ratio declined but did not fall below one.

c. Reduced frequency of human health-based AWQC exceedances in Ohio's water bodies

Baseline in-waterway concentrations of MP&M pollutants exceed human health-based ***ambient water quality criteria (AWQC)*** limits for consumption of water or organisms in three reaches. Two reaches exceeded human health-based AWQC for consumption of organisms only. EPA estimates that the final regulation will not eliminate these exceedences of human health AWQC on any reach but will reduce the number of exceedences on one reach.

22.1.2 Lead-Related Benefits

Total monetized lead-related benefits in Ohio for children and adults under the final regulation are $422,113 (2001$). Chapter 14 of this report describes the methodology used to estimate these benefits.

a. Estimated benefits to Ohio's children

Table 22.2 presents lead-related benefits from the final regulation for preschool age children and pregnant women in Ohio. EPA estimates that the final regulation will reduce neonatal mortality by 0.024 cases annually, with an annual monetary value of $162,094 (2001$).

EPA estimates that the final regulation will avoid the loss of an estimated 26.96 IQ points among preschool children in Ohio, with an annual value of $253,934 (2001$). The annual avoided costs of compensatory education from reduced incidence of children with IQ below 70 and blood lead levels above 20 µg/dL amount to approximately $6,085. In total, the final regulation results in lead-related benefits for Ohio children of $422,113 annually (2001$).

Table 22.2: Ohio Child Lead Annual Benefits (2001$): Final Regulation

Category	Reduced Cases or IQ Points	Monetary Value of Benefits
Neonatal mortality	0.024	$162,094
Avoided IQ loss	26.96	$253,934
Reduced IQ < 70	0.09	$5,345
Reduced PbB > 20 µg/dL	0.04	$740
Total Benefits		**$422,113**

Source: U.S. EPA analysis.

b. Adult benefits

Table 22.3 presents benefit estimates for reduced lead-related health effects in adults. These health effects include increased incidence of hypertension, initial non-fatal ***coronary heart disease*** (CHD), non-fatal stokes (***cerebrovascular accidents*** [CBA] and ***brain infarction*** [BI]), and premature mortality. The final regulation would reduce hypertension in Ohio by an estimated 9.4 cases annually among males, with annual benefits of approximately $10,670 (2001$). Reducing the incidence of initial CHD, strokes, and premature mortality among adult males and females in Ohio would result in estimated benefits of $963, $2,115, and $103,645, respectively. Overall, adult lead-related benefits total $117,393. This analysis does not include other lead-related health effects from elevated ***blood pressure*** (BP) or from effects such as nervous system disorders, anemia, and possible cancer effects.

Table 22.3: Ohio Adult Lead Benefits (2001$): Final Regulation			
Category		Final Regulation	
		Reduced Cases	Monetary Value of Benefits
Men	Hypertension	8.697	$10,670
	CHD	0.011	$693
	CBA	0.005	$947
	BI	0.003	$535
	Mortality	0.015	$79,178
Women	CHD	0.003	$270
	CBA	0.002	$392
	BI	0.001	$241
	Mortality	0.004	$24,467
Total Benefits			**$117,393**

Source: U.S. EPA analysis.

22.1.3 Economic Productivity Benefits

The selected option does not affect POTW operations because the final rule regulates only direct dischargers. For the alternative policy options that consider both direct and indirect dischargers, EPA evaluated two categories of productivity benefits for POTWs:

- reduced ***interference*** with the operations of POTWs, and
- reduced contamination of sewage sludge (i.e., biosolids) at POTWs that receive discharges from MP&M facilities.

Chapter 16 presents the methodology for evaluating POTW benefits. EPA's analysis found that the alternative policy options did not yield POTW productivity benefits in Ohio.

22.1.4 Total Monetized Benefits

Summing the monetary values over all benefit categories (Chapters 21 and 22) yields total monetized benefits in Ohio of $930,408 (2001$) annually for the final regulation (see Table 22.4). As noted in Chapter 12, this benefit estimate is necessarily incomplete because it omits some mechanisms by which society is likely to benefit from reduced effluent discharges from the MP&M industry. Examples of benefit categories excluded from this estimate include: non-lead-related, non-cancer health benefits; improved aesthetic value of waters near discharge outfalls; benefits from improved habitat for wildlife, including threatened or endangered species; tourism benefits; and reduced costs for drinking water treatment.

Table 22.4: Estimated Annual Benefits in Ohio from Reduced MP&M Discharges under the Final Regulation 2001$)

Benefit Category	Low	Mid	High
1. Reduced Cancer Risk:			
Fish Consumption	$14,503	$14,503	$14,503
Water Consumption[a]	n/a	n/a	n/a
2. Reduced Risk from Exposure to Lead:			
Children	$422,113	$422,113	$422,113
Adults	$117,393	$117,393	$117,393
3. Enhanced Water-Based Recreation	$250,932	$250,932	$250,932
4. Nonuse benefits	$125,466	$125,466	$125,466
5. Avoided Sewage Sludge Disposal Costs	$0	$0	$0
Total Monetized Benefits	**$930,408**	**$930,408**	**$930,408**

[a] The monetized cancer avoidance benefits from reduced drinking water contamination are negligible.

Source: U.S. EPA analysis.

22.2 SOCIAL COSTS OF THE FINAL REGULATION

22.2.1 Baseline and Post-Compliance Closures

The methodology used to assess baseline and post-compliance closures differed from the methodology used for the national analysis presented in Chapter 5. The screener data collected for Ohio facilities did not provide financial data to perform an after-tax cash flow or net present value test. EPA therefore used data from the national analysis to estimate the percentage of facilities that close in the baseline and post-compliance. EPA assumed that the frequency of Ohio facility closures would be the same as that found in the national analysis for facilities with the same discharge status, subcategory, and flow category. For example, 2 percent of Oily Wastes facilities discharging less than one million gallons per year close in the baseline in the national analysis, and this same percentage is assumed for Ohio screener direct dischargers in that flow size category.

Table 22.5 summarizes the numbers of facilities in Ohio closing or excluded from the final regulation by discharge status. All indirect dischargers operating post-regulation are excluded from requirements by subcategory exclusions. Of the 198 direct dischargers operating post-regulation, 85 (or 43 percent) are excluded from requirements by subcategory exclusions. A total of 113 direct discharging facilities in the Oily Wastes subcategory are therefore subject to requirements under the final regulation.

Table 22.5: Regulatory Impacts for Ohio MP&M Facilities by Discharge Type			
	Indirect	**Direct**	**Total**
Number of MP&M facilities operating in the baseline	1,682	198	1,880
Number of MP&M facilities with subcategory exclusions	1,682	85	1,767
Number of MP&M facilities operating in the baseline estimated subject to regulatory requirements	0	113	113
Number of regulatory closures	0	0	0
Percent of MP&M facilities operating in the baseline and subject to regulatory requirements that are regulatory closures	0.0%	0.0%	0.0%

Source: U.S. EPA analysis.

22.2.2 Compliance Costs for MP&M Facilities

The calculation of annualized compliance costs in Ohio uses the methodology presented in Chapter 11. These compliance costs are not adjusted for the effect of taxes or for recovery of costs through price increases, and therefore represent the social value of resources used for compliance. EPA annualized compliance costs using a social discount rate of seven percent over an estimated 15-year useful life of compliance equipment.

In calculating compliance costs for Ohio facilities, EPA combined the compliance cost estimates developed for the "detailed questionnaire" Ohio facilities included the national analysis with compliance costs estimated for the additional "screener questionnaire" facilities included in the Ohio analysis. The Agency estimated compliance costs for each Ohio screener facility and then calculated an annualized compliance cost by subcategory, flow range, and discharge status for the Ohio facilities. These costs included facilities that might be assessed as baseline closures and thus would overstate expected compliance costs to the extent that some facilities are expected to close and not incur compliance costs. Because EPA estimated closures among Ohio screener facilities based on the closure rates from the national analysis, it was not possible to identify specific Ohio screener facilities as baseline or post-regulation closures and to remove their compliance costs from the total compliance cost estimates on a facility-specific basis. Instead, EPA reduced the total compliance costs, by facility category, by the estimated fraction of facilities assessed as baseline closures from the national analysis. EPA added these costs for the "screener questionnaire" facilities to the estimated compliance costs for the "detailed questionnaire" facilities to calculate total compliance costs for Ohio MP&M facilities.

Table 22.6 reports the estimated resource value of compliance costs by discharge status and subcategory. The total estimated annualized compliance costs are $62 thousand.

Table 22.6: Resource Value of Compliance Costs in Ohio (2001$)			
Subcategory	**Indirect**	**Direct**	**Total**
General Metals	$0	$0	$0
MF Job Shop	$0	$0	$0
Non Chromium Anodizer	$0	$0	$0
Oily Wastes	$0	$62,232	$62,232
Printed Wiring Boards	$0	$0	$0
Railroad Line Maintenance	$0	$0	$0
Steel Forming & Finishing	$0	$0	$0
Total	**$0**	**$62,232**	**$62,232**

Source: U.S. EPA analysis.

22.2.3 Total Social Costs

As discussed in Chapter 11, the regulation's social costs include the resource cost of compliance (e.g., labor, equipment, material, and other economic resources needed to comply with the rule), costs to governments administering the regulation, and the social costs associated with unemployment resulting from facility closure. EPA estimated that the final rule will not result in social costs of unemployment and that governments will not incur additional costs in administering the regulation. Accordingly, as shown in Table 22.7, EPA's estimate of the final rule's social costs in Ohio is the same as that reported for the resource cost of compliance, $62 thousand (2001$) annually.

Table 22.7: Annual Social Costs for the Final Regulation in Ohio (2001$, costs annualized at 7%)

Component of Social Costs	Final Rule
Resource value of compliance costs	$62,232.0
Government administrative costs	$0.0
Social cost of unemployment	$0.0
Total Social Cost	$62,232.0

Source: U.S. EPA analysis.

22.3 Comparison of Monetized Benefits and Costs in Ohio

EPA cannot perform a complete cost-benefit comparison because not all of the benefits resulting from the final rule can be valued in dollar terms. As reported above, for Ohio, EPA estimated the final rule's social cost at $62 thousand annually (2001$) and estimated monetizable benefits of $930 thousand annually (2001$). Subtracting the social costs from social benefits yields a net monetizable benefit of $868 thousand annually (2001$).

In contrast to the national estimates of costs and benefits for the final regulation, the Ohio case study shows substantial net positive benefits even for the lower-bound benefits estimate. This difference results mainly from the more complete assessment of benefits from reduced MP&M pollutant discharges and more detailed water quality modeling. In addition to estimating recreational benefits from reduced frequency of AWQC exceedences, the Ohio case study estimated changes in water resource values from reduced discharges of TKN. Changes in TKN concentration in Ohio water bodies account for approximately 96 percent of the monetary value of recreational and nonuse benefits from the final rule. EPA also included an additional recreational benefit category in the Ohio analysis: swimming. Although the estimated per-trip welfare gain to swimmers is less than the gain for participants in other water-based recreational activities, this benefit category accounts for a sizable portion of the state-level benefits. Other factors that affect the Ohio benefit-cost comparison include: the presence of unique water resources such as Lake Erie; use of a more sophisticated water quality model, which estimates water quality changes in reaches downstream from the discharge reach; and a more accurate account of baseline water quality conditions. The presence of unique water resources, such as Lake Erie, and other numerous recreational opportunities (e.g., inland lakes, rivers, and reservoirs), suggest that the estimated benefits for Ohio are likely to be higher than the average of benefits for other states.

GLOSSARY

ambient water quality criteria (AWQC): levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes. (http://www.epa.gov/OCEPAterms/aterms.html)

blood pressure (BP): the pressure of the blood on the walls of the arteries.

brain infarction (BI): stroke.

cerebrovascular accidents (CBA): stroke.

coronary heart disease (CHD): disorder that restricts blood supply to the heart; occurs when coronary arteries become narrowed or clogged due to the build up of cholesterol and fat on the inside walls and are unable supply enough blood to the heart.

interference: the obstruction of a routine treatment process of POTWs that is caused by the presence of high levels of toxics, such as metals and cyanide in wastewater discharges. These toxic pollutants kill bacteria used for microbial degradation during wastewater treatment (see: microbial degradation).

publicly-owned treatment works (POTW): a treatment works as defined by Section 212 of the Act, which is owned by a state or municipality. This definition includes any devices or systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature. (http://www.epa.gov/owm/permits/pretreat/final99.pdf)

ACRONYMS

AWQC: ambient water quality criteria
BI: brain infarction
BP: blood pressure
CBA: cerebrovascular accidents
CHD: coronary heart disease
POTW: publicly-owned treatment works

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